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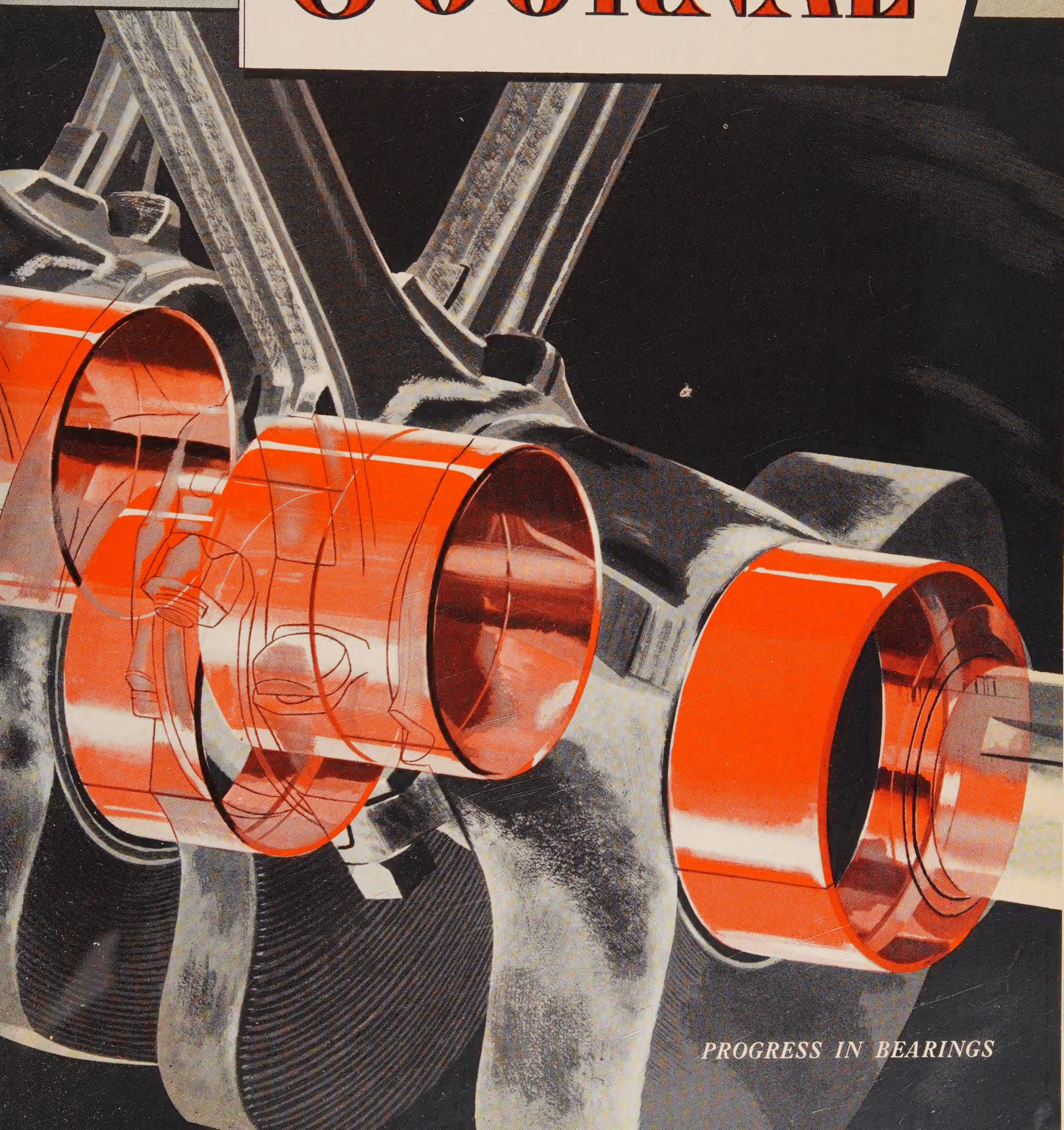

PROGRESS IN BEARINGS

Some Thoughts on Competitiveness

AMERICA'S economy flourishes because of honest competition. Each year competitors in the automotive industry introduce new models with proud proclamations of engineering and design advances and each year buyers by the millions seek out the particular vehicles which they believe will best serve their purposes. The proof of excellence lies in the market place.

Competitiveness surges everywhere around us. Even our system of engineering education engenders it. Students consciously or unconsciously pit their ability to learn against the talents of their friends and classmates. Here, individual achievement comes into focus in the final examination which sternly seeks to measure the learning of a semester or term. The proof of excellence lies, for that moment, in the final rating.

To be a successful competitor in any task requires individual initiative. There are as many ways for a manufacturer to build a motor vehicle as there are for a student to explain Newton's laws. An automobile is built to obey certain fundamental physical laws, but an automobile itself consists not of the physical laws but of mechanisms designed on the basis of how men interpret and interrelate fundamental knowledge of these laws. Newton's laws can be stated succinctly but interpretations and applications of the laws may vary to great degree.

General Motors, considered as a technical organization, recognizes that sincere, technically minded individuals can be most productive if there are no firm dictates from the central organization on the hundreds of technical decisions which must be reached before any product—an automobile, a locomotive, a jet engine, a refrigerator, an electric motor, or a crop dryer—can be produced and marketed. The entire organization has grown with the strengths which come from decentralized operation which places the maximum responsibility for decisions on the majority of operating problems at the Divisional and plant level. Thus it is that 1954's line of new automobiles and other products display radically different technical aspects. In automotive engineering there are many schools of thought on what kind of transmission ought to be used. There are many differences among the engines of the automobiles and the body designs are, of course, highly individualized. In fact, the buyer, in many cases, is given the option on many basic technical choices such as type of transmission and engine. Body style, color, and accessories are entirely his choice.

To organizations operating on a centralized basis, this system that places maximum responsibility at the local level with assistance and broad guidance from the central organization, might appear uneconomical. However, the market place has proved that the decentralized system is sound.

Manuscripts in the JOURNAL frequently may reflect basic differences of opinion among the operating units within General Motors. The fundamental technical knowledge is well understood by our engineers—thanks to the nation's educational system. Interpretations of fundamental technical knowledge can and do vary. The purpose of the JOURNAL is to report the interpretation and application of fundamental laws as they are exhibited by our Divisions. We know that every one of their products is honestly conceived and diligently manufactured. We know, too, that the technical decisions which go into a product are tested in the market place, where trickery or poorly conceived applications could not live long.

Honest competition prevails also within the General Motors organization. There is no disagreement among GM's engineers on fundamental laws but there exists strong competition in the interpretations of these fundamental laws.

John F. Gordon

John F. Gordon,
Vice President and Group Executive

THE COVER

In the fourth of a cover series portraying transportation developments, Artist John Tabb's design directs attention to automotive bearings. Power is represented by the connecting rods and crankshaft inside an automobile engine. At the juncture between these two engine components, where large forces must be transmitted, is a bearing of relatively small size. That this small size has been retained, and in some cases reduced, while engine power, speed, and compression ratio have increased over the years is an achievement in metallurgy. Better materials, better lubricants, as well as improvements in engineering design, have made possible the modern bearing. Result: the motoring hazard of the burned-out bearing is rare indeed today.

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The Work and Contributions of the Process Development Section

(Fourth of a Series on GM organizations)

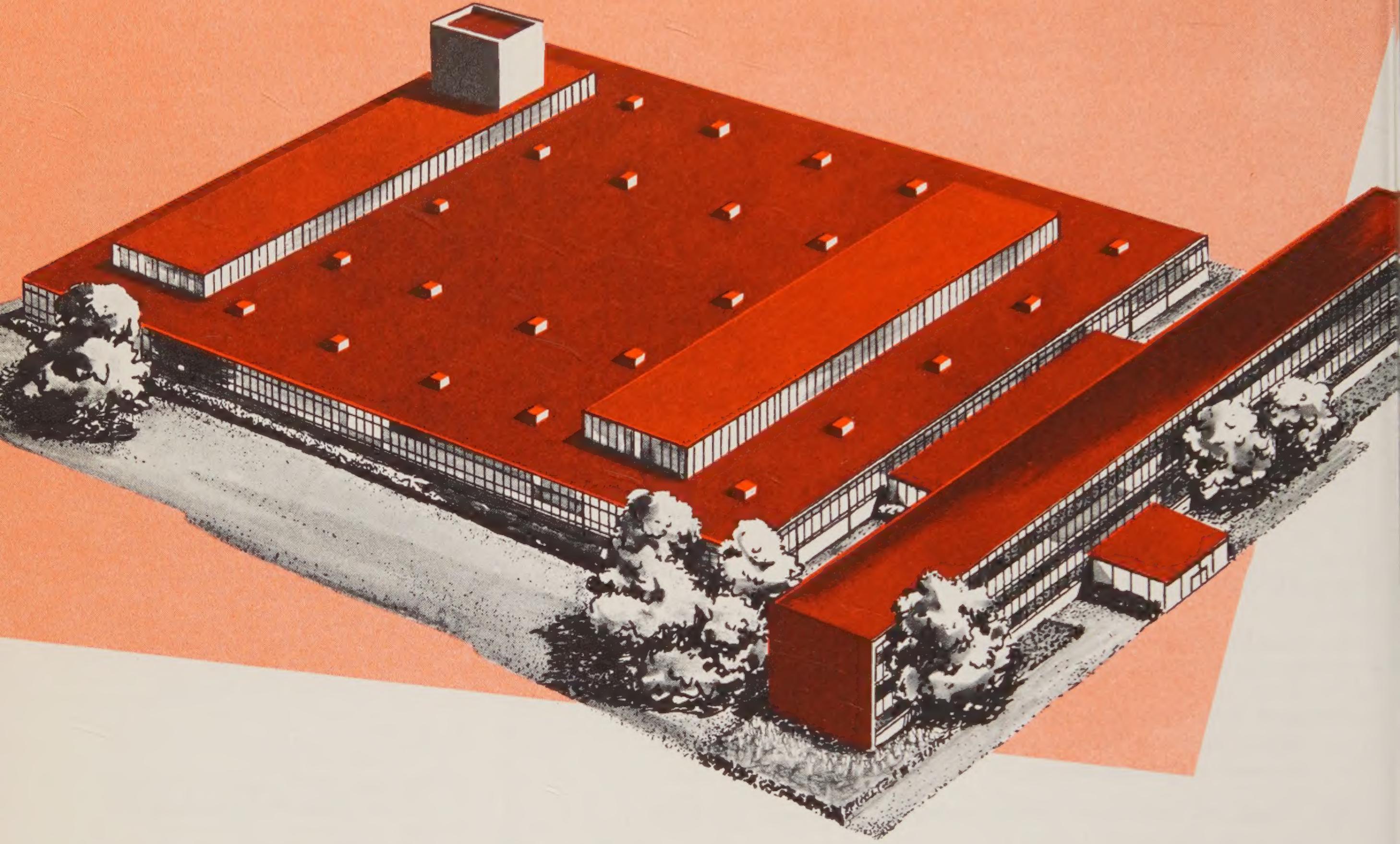


Fig. 1—Process Development Section group of buildings at the General Motors Technical Center, located north of Detroit. The new buildings, scheduled for occupancy in 1954, will consist of an office building of 78,872 sq ft and a shop building of 191,619 sq ft. The shop building will contain project areas, machine shops, laboratories, and an experimental production foundry.

Improving the techniques and processes of manufacturing is not a new objective in industry. In General Motors, improvements of this kind have been made over the years by the various Divisions, generally on an individual basis. Recently, a number of considerations have indicated that there would be advantages to be realized from a centralized group which would supplement the work of the GM Divisions in achieving manufacturing improvements. The result has been the formation of the Process Development Section which combines the experience of its engineers with the valuable background of the Divisions to develop automatic machines, new manufacturing processes, better material utilization, and many other production helps that go beyond known methods. Better working conditions, greater safety for employes, and reduction of costs are some of the benefits gained from this work.

The Process Development Section of General Motors was established in 1946 as an activity of the Manufacturing Staff to provide a technical group to specialize in the improvement of manufacturing processes. Prior to this time the development of unusual manufacturing processes was undertaken by each Division, and it was believed that a central process development organization could contribute considerable assistance to the Divisions for several reasons:

(a) The pressure of everyday production problems often interferes with long-range development work.

(b) Many manufacturing and assembly plants do not have available

By RODGER J. EMMERT
General Motors
Manufacturing Staff

How engineers
develop
improved processes

adequate laboratory, engineering, and machine-shop facilities for this type of work.

(c) The solution of production problems sometimes requires the group knowledge of engineers trained in specialized fields.

(d) The accumulated experience of a central group is readily available to all of the plants of General Motors.

(e) Such a group can be of assistance in bridging the gap between the work of the Research Laboratories, the Engineering Staff, and the production organization, by developing methods and equipment to economically manufacture new products and prove the process before any large-scale manufacturing is attempted.

During the short span of years since this Section was established, a capable group of experienced and young engineers has been gathered together. It is acquiring a valuable background of experience which is enabling it to tackle some of the more complicated problems which arise. In this short space of time, the Section has developed some new and unusual equipment for manufacturing, assembly, and inspection. Expanded facilities will soon become available in a new building at the General Motors Technical Center, located just north of Detroit (Fig. 1). With the new building and improved facilities it is hoped that the Section will be in a position to offer considerably more assistance to the Divisions in solving manufacturing processing problems.

An analysis of the many projects so far completed permits classifying them into several functional groups. The following examples discuss and illustrate these groups.

Development of a Basic Manufacturing Process

A machine, from its physical appearance, usually does not portray the basic development, experimentation, and engineering knowledge that was required to produce it. In Fig. 2 may be seen an example of equipment that represents several years of developmental work in perfecting a new process and adapting it for production application. This process has been named *gyro-finishing* and its function is to finish decorative parts, prior to electro-plating. The part is suspended in a rotating drum of loose abrasive material that removes the parent metal equally as it flows over and around the part, thereby producing a polished surface.

The idea of plowing the parts through an abrasive mixture was first tried out experimentally in a drum mounted on a drill press and was found to have considerable merit. An experimental machine then was designed and built which proved adaptable to polish a variety of parts. The excellent quality of finish thus obtained and the low cost of the operation indicated that the process would be both practical and economical.

High-production gyro-finishing machinery was designed for specific uses, and a number of machines were built and put to work in plants where they are now in everyday use. They have been used to finish copper-plated parts, zinc-base door handles, hood ornaments, and steel stampings, indicating the versatility of the process. The adaptation of this equipment reduces operating costs and substantially improves working conditions in polishing departments.

Development of Special Equipment

One of the major functions of this organization is to work with the Tool, Process, and Production Engineering Groups of the Divisions in developing new processes and equipment to reduce manufacturing costs and improve quality.

Assembly

A semi-automatic radiator-cap assembly machine, illustrated in Fig. 3, exemplifies automation in assembly operations. Three out of five parts are fed automatically and are assembled on an indexing carrier. The completed radiator cap is functionally tested following assembly. The development of this automatic inspection operation was an important contribution which influenced the adoption of this machine.

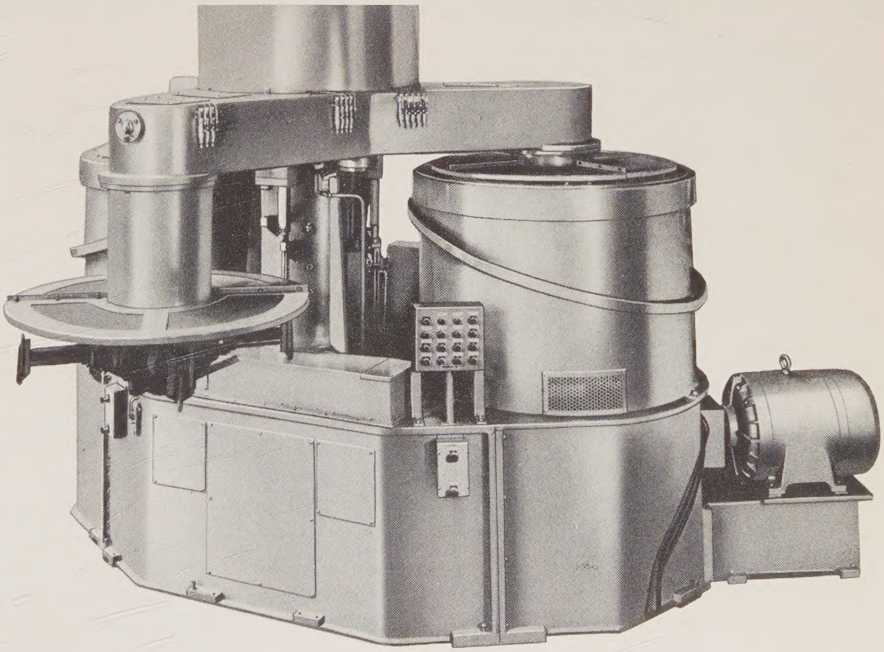


Fig. 2—Development of a new process resulted in this production gyro-finishing machine built for medium-volume production of zinc die-cast ornaments and emblems. Prior to electro-plating, the ornaments and emblems must be polished, and this is accomplished by means of a rotating drum carrying a free abrasive mixture. The machine represents several years of development work in perfecting a new process and adapting it for production application.

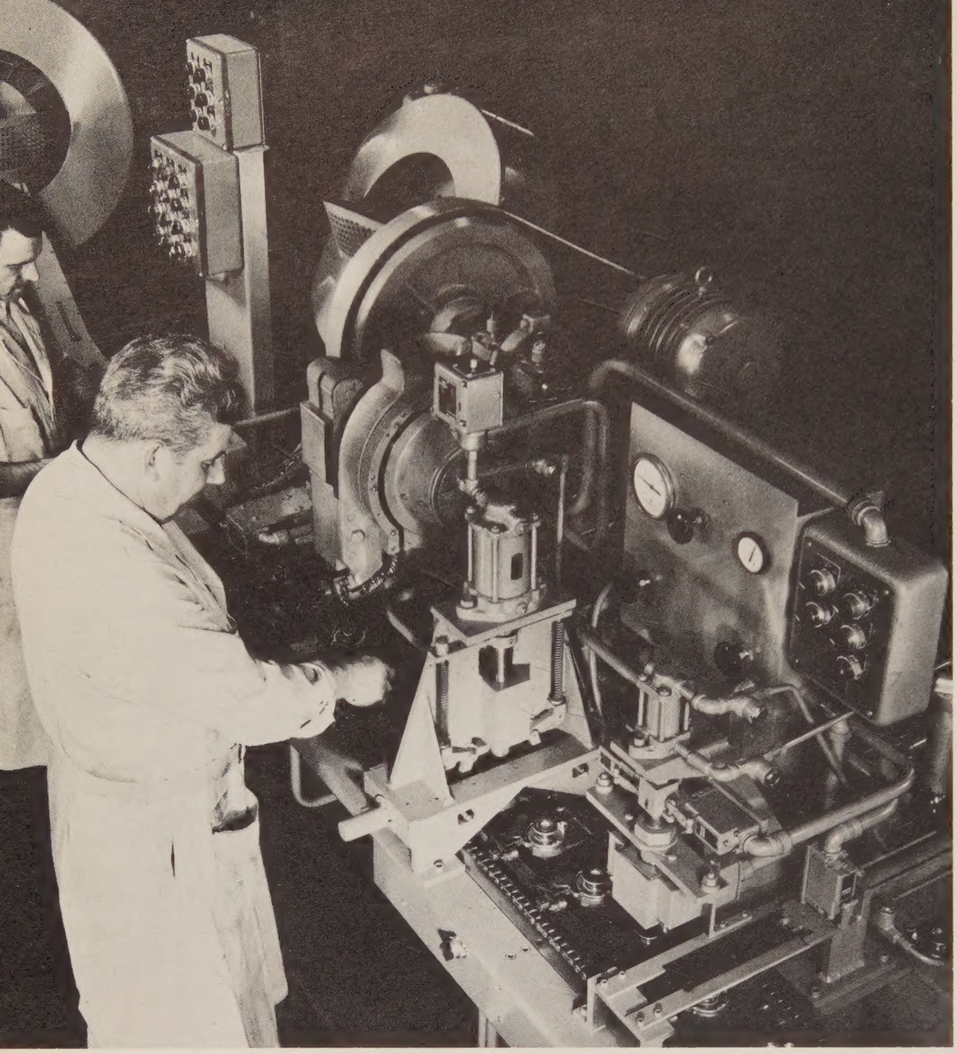


Fig. 3—Semi-automatic radiator-cap assembly machine, developed by the Process Development Section, is now in use at a GM manufacturing Division. Adaptable to assemble five different cap models, the machine provides functional inspection for the spring rate and sealing quality of the part.

Manufacturing Process

A special machine was developed to automatically deburr die-cast carburetor bodies. It has eliminated a tedious and costly hand-deburring operation through the adaptation of a grit-blasting process. Experimental tests with various materials revealed that a stream of granulated walnut shells under high velocity could effectively remove burrs, and a semi-automatic machine was built for the purpose. The principle of operation is the projection of walnut-shell particles by means of air blasts to selected areas on the carburetor castings as they are conveyed through the machine. Fig. 4 shows the various nozzles that direct the blasts to the numerous recessed areas and cavities in carburetor bodies. The use of this machine in production not only has reduced manufacturing cost, but also has improved the quality of the product.

Inspection

Gauging and inspection problems are a challenge to mechanical and electronic ingenuity in the manufacture of interchangeable precision parts at high production rates. An electronic development resulted in the construction of the copper-strip gauge shown in Fig. 5. This device is providing a means of measuring accurately the thickness of dead-soft copper strip as it passes between gauge heads at the rate of 300 fpm in one of the General Motors manufacturing plants. The gauge head acts as a condenser in an amplifying circuit, measuring the thickness of the copper within an accuracy of 0.0001 in. without touching the copper. Following the completion of this equipment, an additional feature was developed that checks the strip for the presence of pin holes as small as 0.001 in. in diameter as the strip passes through the gauge. The development of this gauge has provided an improved method for this rolling-mill operation, and has brought about considerable material savings through the more accurate thickness control of this expensive material.

Foundry

At times, known methods and available equipment fail to reproduce results that have been accomplished by disagreeable hand labor and such a situation existed in one of the GM foundries. Ordinary core-blowing equipment had been tried unsuccessfully to make 43-lb barrel cores for an engine block. Process Development engineers attempted to blow these cores and found that it was not possible to secure the proper density of sand in certain areas of the core. However, by forcing rods into the blown core they found that it was possible to ram the sand to the proper density in these areas. Even with this operation, it became necessary to conduct many experiments to develop a sand mixture which would produce a satisfactory core. Since the force necessary to push the 1-in. diameter rods into the core required more force than could be applied by an individual, it was apparent that mechanical equipment, combining the core-blowing operation with a hydraulic press for ramming the cores, would be necessary.

Preliminary designs of such a machine were made up for discussion with the foundry engineers and foundry management, after which it was decided that a small scale model of a proposed machine would be made to better visualize the construction of the machine and to determine whether a full scale model should be built. The construction of the actual machine involved many problems, such as the requirement to move a 1,500 lb mechanism a distance of several feet within a period of 4 or 5 sec in order to obtain the maximum production from the machine.

To design such a machine to stand up and operate continuously in the presence of sand required considerable ingenuity. However, two machines subsequently were built and put into operation (Fig. 6). They have eliminated the disagreeable hand labor that was required formerly and have reduced substantially the cost of the operation. They have greatly improved working conditions in

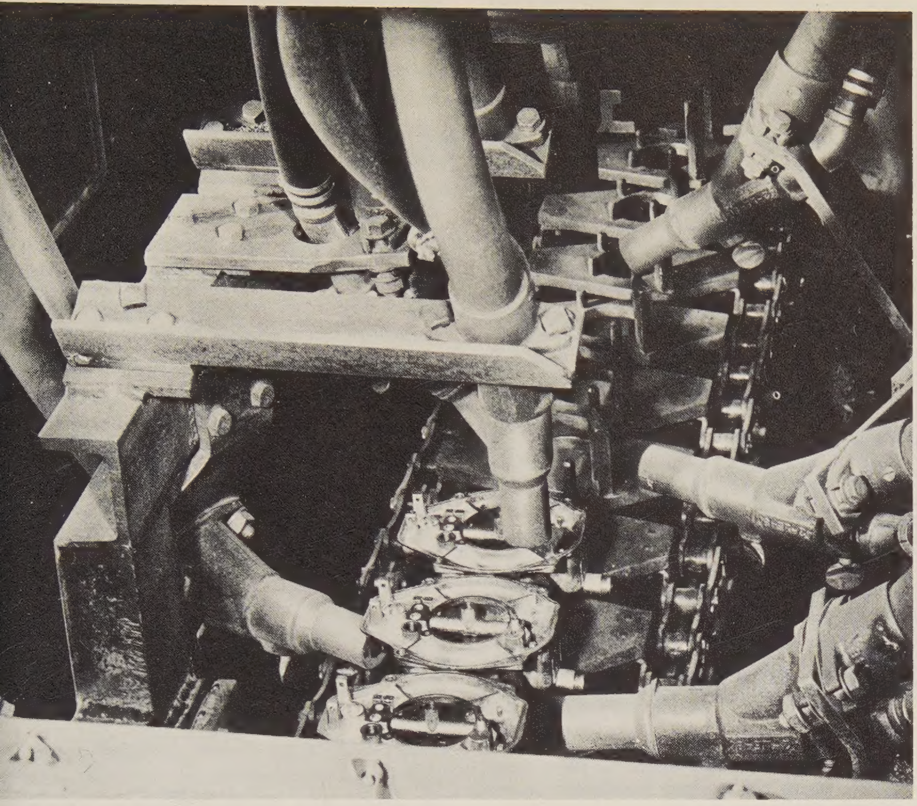


Fig. 4—An inside view of a deburring machine which uses a grit-blasting process that was developed for the automatic deburring of die-cast carburetor bodies. With the use of the various movable nozzles shown, a blast of walnut shells can be directed to selected recessed areas and cavities on the carburetor castings as they are conveyed through the machine.

that department and have solved a critical problem of training operators for this particular job.

Development and Operation of Pilot Lines

Another activity of the Process Development Section is the development of pilot production lines sometimes necessary for the evaluation of a new manufacturing process. It is sometimes highly desirable to provide machinery and equipment for the production of new products developed by the Engineering Staff and to try out such equipment before turning the problem over to the manufacturing plant.

Before March 1951, chrome-plated, cast-iron piston rings were used in Diesel engines, and considerable breakage of these rings occurred in service due to the fact that the rings passed over intake and exhaust ports in the cylinders. Chrome-plated steel rings solved the problem, but were found to be very expensive. Process Development was requested to study the problem and develop a process of manufacture which would result in the production of a ring low enough in cost to permit its use. Based on an economical evaluation of this study, a complete pilot-line installation was authorized.

It was found that round wire could be rolled into a rectangular cross section and, at the same time, necessary oil grooves could be rolled into one edge. Although the rectangular wire then could be forced into circles and cut off very accurately to length, the real trick in the process was to develop equipment that would grind the rings perfectly round. Additional problems arose in the development of special fixtures for holding the rings to proper form during the heat-treating and tempering operations. Considerable experimental work involving high current densities and controlled temperatures of the plating solution was required in order to secure a heavy coating of chromium on the outside diameter of the ring in a reasonable length of time. This process resulted in the plating of chromium at a much higher rate than is practiced ordinarily in the decorative arts.

It readily can be seen from the successful completion of this project that it is very desirable at times to set up all the machinery and equipment to manufacture quantities of a new product and completely develop an exact manufacturing process.

In another case, equipment was set

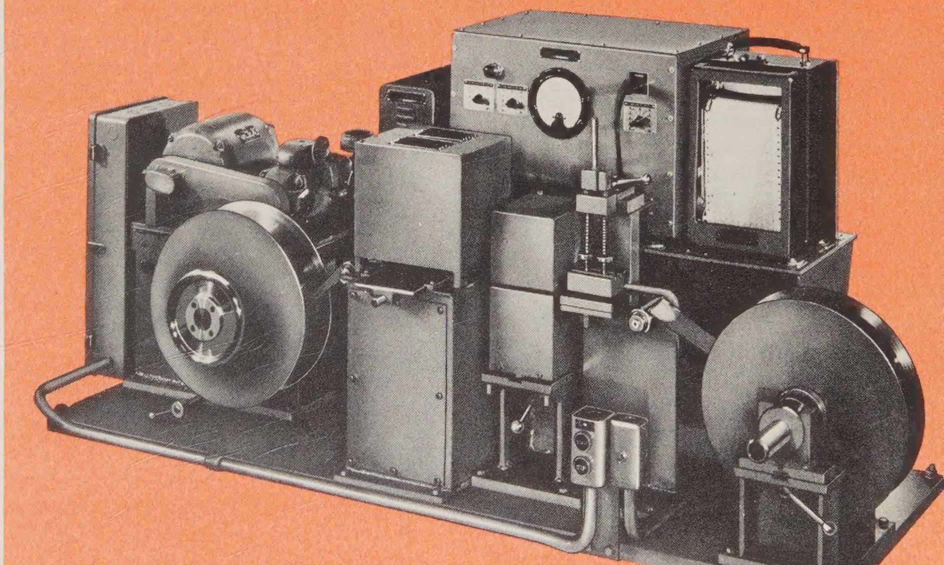


Fig. 5—Copper-strip gauge used to measure accurately the thickness of dead-soft copper strip. This electronic development enables the inspection of this material at the rate of 300 fpm.

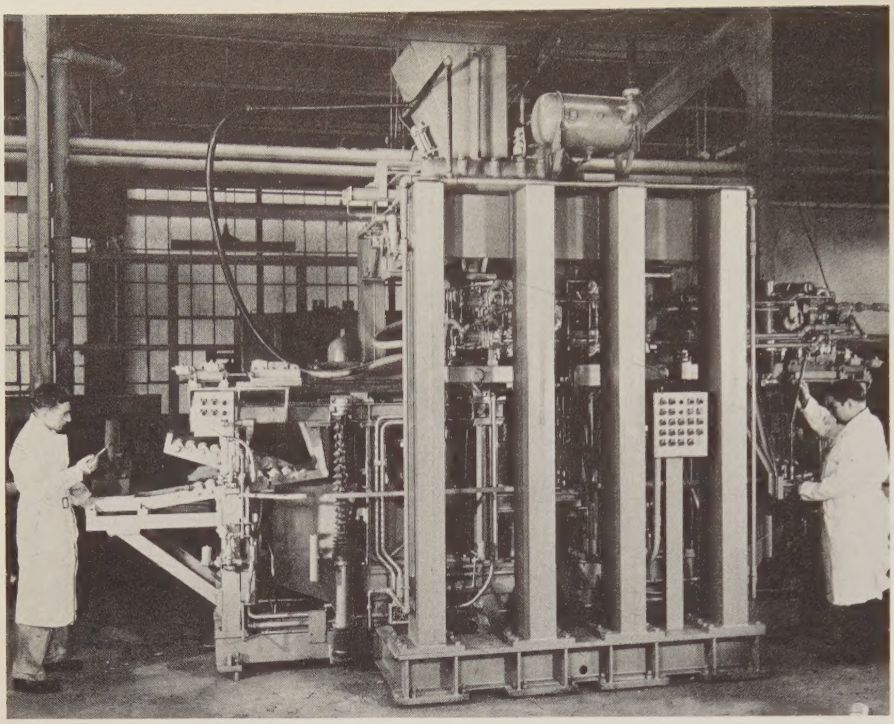


Fig. 6—This core-making machine is an example of making new adaptations of existing processes. Engineering specialists from several fields combined their efforts to produce this automatic barrel-core machine used in the production of sand cores for automotive engine blocks. After installation, these machines improved working conditions in the area and reduced manufacturing costs.

up in the Process Development laboratory to work out a process of plating nickel onto jet-engine parts without the use of electrical current. The purpose of the plating is to permit the use of carbon steel instead of stainless steel and still overcome the problem of corrosion. The desired objective was to plate an even coat of nickel over all surfaces and crevices of the jet-engine parts, and keep the coating thin enough to eliminate interference in the assembly of mating parts. It is practically impossible to accomplish this by the electro-plating process. A solution of nickel compounds can be made up to accomplish this result; however, the maintenance of such a solution has been baffling. By setting up a pilot line and working with such a solution, plating engineers developed an operating procedure which maintained the life of the solution and simplified the problems of properly controlling it. Thus, a laboratory technique was developed into a successful production process which may save many hundreds of pounds of scarce nickel.

Evaluation of New Processes for Specific Purposes

The engineers of Process Development also cooperate with the Divisions in the investigation of manufacturing processes originating outside of the organization. New processes are tested and evaluated for their economic possibilities with regard to specific applications.

A new process that has been publicized considerably in recent years is the cold extrusion of steel. Originating in Germany during the early thirties, the extent of the development was not generally known until after World War II when the U. S. Government made available full reports on the work. Process Development initiated preliminary development work early in 1949 and has since produced many parts by the process. However, the work is still of an experimental nature for there are some unknowns yet to be solved. The process not only offers material savings but also provides desirable features such as closely held dimensions, good grain structure, and excellent surface finish. It is because of these potential advantages that development work will be continued.

Production Adaptation of a New Process

The Ternstedt Division of General Motors, in searching for an improved method of coating interior trim moldings, developed an electro-static painting process that was both practical and economical in the use of paint. Process Development Section contributed to the system by developing high-voltage generating equipment which had inherent safety features with respect to employes and fire and which could be built economically.

Engineers at Process Development recognized that the process had wide application possibilities throughout the entire General Motors organization. Therefore, as a means of evaluating the adaptability of the process to the coating of parts in other Divisions, a flexible production painting facility was set up in the Section. After experimental work in this unit, equipment was made and installed in Divisions and is being used to coat a wide variety of parts ranging from hard-rubber steering wheels to rear-axle assemblies.

The painting process is explained simply in Fig. 7. The paint is sprayed through an ionized field established between sharp-pointed discharge electrodes and a grounded collector plate. The finely atomized paint particles thus are electrically charged to a high potential and, when sprayed in the direction of parts on a moving conveyor, are attracted to the parts which are grounded. This attraction of paint particles to the parts reduces the over-spray losses inherent in air-gun spraying operations.

GM Material-Utilization Program

Another subject of importance throughout General Motors is the Material-Utilization Program which has been promoted by the Process Development Section. The Program was organized to call attention to the fact that considerable savings could be realized from the better utilization of material and to stimulate interest throughout all GM Divisions in making savings.

The fact that over one-half of General Motors manufacturing dollars are spent for materials used in the manufacture of its products gives an indication of the tremendous savings that can be realized. Although the Divisions are responsible for the effective use of materials and the development of tools and methods, the Process Development Section has been able to stimulate interest and obtain action by collecting examples of savings that have been made by Divisions and distributing this information to all General Motors plants. It has encouraged the formation of committees in each plant

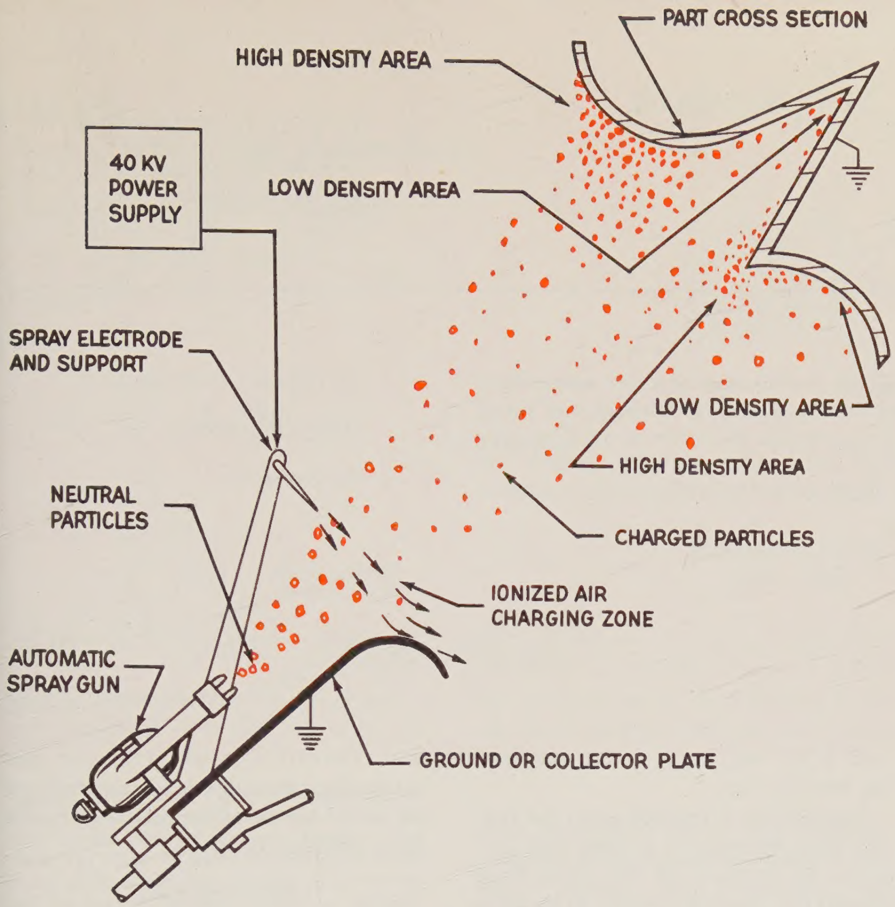


Fig. 7—This diagram illustrates the Ternstedt spray-painting principle which has been found adaptable to a wide variety of parts ranging from hard-rubber steering wheels to rear-axle assemblies. The paint is sprayed through an ionized field established between needle electrodes and a grounded collector plate. The finely atomized paint particles are electrically charged to a high potential and, when sprayed in the direction of parts on a moving conveyor, are attracted to the parts which are grounded.

to work on the problem and a meeting is held once a year to report the results that have been achieved. A material savings of over fifteen million dollars was reported during the past year by adopting suggestions resulting from this Program.

Conclusion

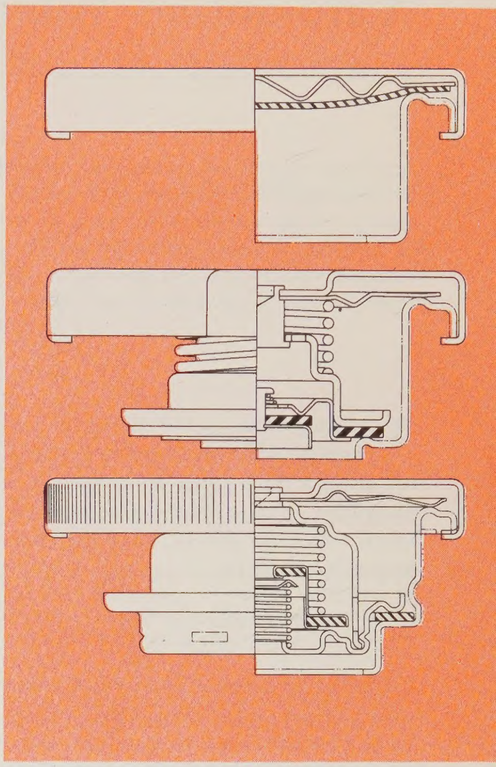
Practically every Division now has a manufacturing development section but these Divisions are, nevertheless, calling on the General Motors Process Development Section for experimental work and assistance. Ideas to improve manufacturing develop faster than they can be worked out and put into actual use. The necessity of getting ideas adopted quickly in order to realize their savings and advantages requires developmental work that is above the capacity of the average plant. A competitive spirit has developed among the Divisions in their effort to accomplish manufacturing-process improvements and increased savings.

The Process Development Section has a group of men who constantly are contacting master mechanics and supervision in various GM plants to offer assistance, where practical, and to report on projects that have been undertaken. Thus, the Section stimulates activity among the Divisions and accomplishes much in coordinating the variety of manufacturing development work that is undertaken.

When the new facilities have been completed at the General Motors Technical Center, this Section will be able to increase the number of projects that it can accept and likewise will be expanding its staff of engineers who have the imagination and the ability to solve the many problems that develop.

The Process Development Section will be called upon to develop technological improvements that go beyond known methods in the never-ending search for progress. For, as General Motors continues to improve the quality of its products, it also must strive continually to reduce the manufacturing costs. It is through better methods and greater individual productivity that the standard of living of all of the people will be raised.

CORRECTION ON RADIATOR-CAP IDENTIFICATION

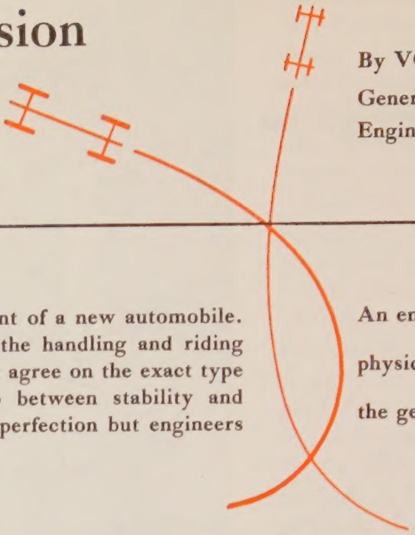


The chronology of pressure-type radiator-cap development was inaccurately shown on page 4 of the January-February 1954 General Motors Engineering Journal in Fig. 2 of the paper "Major Cooling Problems Encountered in Today's Automobiles." The author, Harold A. Reynolds, Harrison Radiator Division, has called attention to incorrect editorial identification of the lowermost of the three caps as today's spring-loaded pressure cap. Actually, this cap was the predecessor of the cap in the center, which is today's design.

In today's cap (center) both the inner and outer Neoprene seals (cross-hatched) are part of the cap structure, whereas the former design (bottom) employed two inner Neoprene seals as part of the structure and the important outer gasket was of fiber and attached neither to the radiator neck nor to the cap and frequently became nicked or lost in use. Aside from more dependable efficiency, the new design offered greater ease of manufacture as an inspection of the two caps would indicate.

The simple cap (top) was not of the pressure type.

An Analysis of the Suspension Problems of the Automotive Vehicle



By VON D. POLHEMUS
General Motors
Engineering Staff

Analytical suspension studies are a necessity in the development of a new automobile. On application of geometric and mathematical tools depends the handling and riding qualities of the vehicle. Customers, as well as engineers, do not agree on the exact type of handling desired, especially on the optimum relationship between stability and maneuverability. It is not possible to use any single guide for perfection but engineers strive for the best possible compromise.

An engineer views the physics that defines the geometry

THE magnitude of the subject of suspension of the automotive vehicle is self-evident. This paper is confined to a discussion of some of the fundamentals about which the general handling characteristics are built.

The Hypothetical Case—Turn without Roll

Driving an automobile over an uneven road produces many actions between the various chassis elements other than those controlled by the driver. From the steering and handling standpoint the driver controls only one of these actions, that of steering the front road wheels. First, it is necessary to outline the basic conditions that result from the turning of the steering wheel in any given steering maneuver.

To simplify the discussion, consider a hypothetical car that has no *oversteer** or *understeer* and is without roll (Fig. 1). By turning the steering wheel the driver turns the front road wheels through a steering angle α relative to the centerline of the car. For the instant the car continues to go straight ahead, the steering angle α becomes the front *slip angle* ϕ_1. This slip angle is the angular displacement between the actual path of the wheel and its fore-and-aft vertical plane. It produces a cornering force F_1 that pushes the front end of the car into the turn and gives a rotary acceleration.

During transition the front end of the car has moved into the turn while the rear end continues straight ahead. This has given the rear end an attitude angle, which in this case is the rear slip angle ϕ_2. This angle produces a rear side force F_2 which, however, at this instant is still very small, so that there is an excess of side force F_1 at the front. This excess of side force at the front keeps the car accelerating into the turn.

Equilibrium is reached when the rear side force increases to a point that balances the moment of the front force around the center of gravity. With these forces in balance the car in equilibrium will traverse a curve of constant radius. In this example, the final front slip angle is equal to the rear slip angle. The radius of the curve is theoretically equal to the *Ackerman radius*, and the car neither oversteers nor understeers.

If the initial steering angle α is larger, the rotary acceleration also will be larger and all forces increase proportionally. The whole process runs through in about the same time, although the equilibrium curve will be sharper. A change in car speed has little effect on the time required to reach equilibrium. The distance traveled during transition, however, becomes longer with higher car speeds.

Fig. 2 shows the same hypothetical car without roll but with oversteering or understeering. Since there is no roll, this oversteer or understeer must be considered as the kind produced by an unbalance of slip angles, or slip-angle steer.

In the car previously described, the center of gravity was considered to be at the center of wheel base, and in equilibrium the front and rear slip angles were equal.

Assuming that the understeering car A has its center of mass moved forward, a given initial steer angle does not produce enough side force to overcome the added inertia and the car steers out of the curve.

Car C which has the center of mass moved to the rear will, however, oversteer. The rear slip angle in this case does not produce enough side force to balance the added inertia at the rear and the car steers into the curve.

Cornering Force

The preceding discussion actually has been a study of a tire function on a car and, since the tires are the connecting link between the car and the ground, it is appropriate to digress at this point to consider some of their more rudimentary characteristics (Fig. 3).

The first and most basic conception of a tire is that, if it is to develop a side force, it must slip at an angle to its normal path. This force per degree of slip angle is the cornering force or *cornering power*.

The cornering or side force increases more or less proportionally to the slip angle, up to an angle of approximately five degrees. In this range an average tire develops approximately 150 lb side force per degree. At angles above five degrees this force falls off rapidly until the tire can develop no more force and at this point it skids.

It may be more accurate to say that the tire starts skidding at about five degrees when the rise in cornering force begins to fall off, and the skidding increases gradually from this point up to the point where the curve flattens off and a full-skid condition results.

The side load for full skid is a function of the vertical load on the tire. A tire when normally loaded reaches a full-skid condition at a lateral force of approxi-

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*Glossary on page 13.

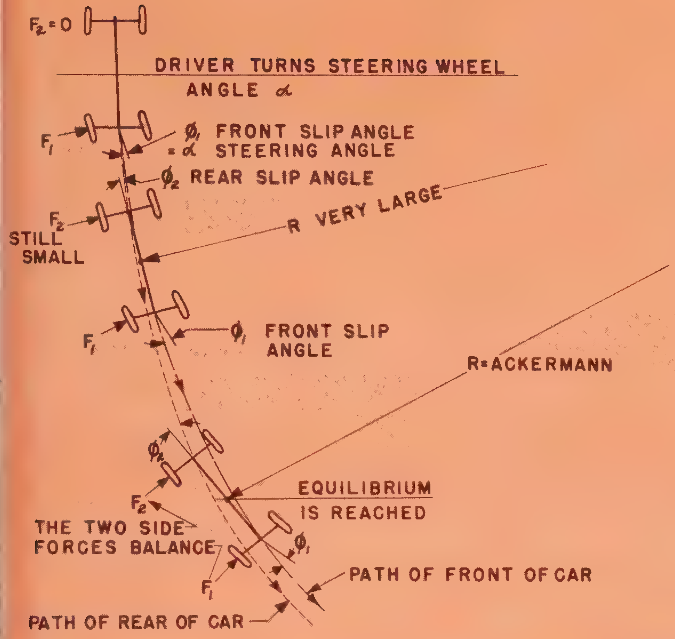

Fig. 1—Existing conditions of a hypothetical car having no oversteer or understeer and without roll when an initial steering maneuver of angle α takes place. The center of gravity is considered at the center of the wheel base. Equilibrium is reached and the car will traverse a curve of constant radius, when the side force F_1 balances side force F_2 and the front and rear slip angles are equal.

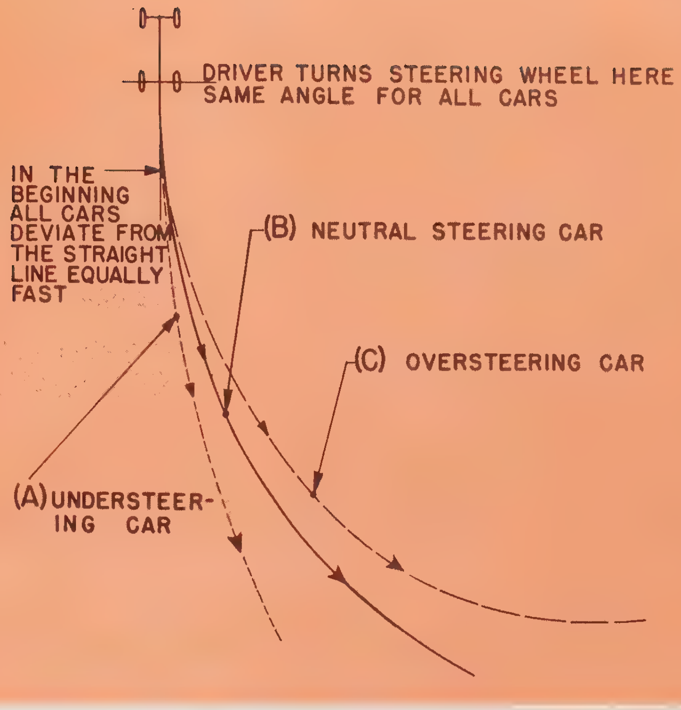

Fig. 2—Hypothetical car of Fig. 1 without roll but with oversteering or understeering due to unbalance of slip angles. Car **A** steers out of the curve due to the front slip angle not being able to produce enough side force to overcome the inertia caused by the center of gravity being moved forward. Car **C** steers into the curve due to the rear slip angle not being able to produce enough side force to overcome the inertia caused by the center of gravity being moved to the rear.

mately 80 per cent of the vertical load. This is apparent since the coefficient of friction of a tire on dry concrete is about 0.8. If the tire is loaded at 50 per cent normal rated load, it reaches a full-skid condition at a side force of approximately 100 per cent of the vertical load. Conversely, if the tire is overloaded to 150 per cent of rated capacity, it skids at a cornering force of approximately 70 per cent of the vertical load.

Specifically, a tire of 1,000-lb vertical-load capacity operating at 50-per cent rated load, at rated load, and at 150-per cent rated load skids or reaches its maximum cornering ability at side forces of 1,000 lb, 800 lb, and 700 lb, respectively. Thus, it is apparent that as the tire load is increased, its relative maximum cornering ability decreases.

Camber is another basic tire condition that produces a side force. A cambered wheel (Fig. 4) follows a circular path about a point which is at the intersection of its centerline and the ground. This creates a slip angle that produces a side force.

The slip angles produced by the normal range of camber angles are relatively small, so the side forces are approximately proportional to the camber angles. A ten-degree camber angle produces a side force or camber thrust of approximately 120 lb.

Roll Axis and Moment

Going a step further from the strictly theoretical car described above, consider that the lateral acceleration of a car in a turn creates a roll moment about a roll axis (Fig. 5). This axis is a hypothetical line connecting the front and rear roll centers of the car. Dynamically, this line may not be the actual axis of roll, but its importance lies in the fact that the roll angles are proportional to the distance from it to the applied force. In other words, a car with a low roll axis rolls through a greater angle when an applied force is exerted at the center of gravity than does one with a high axis.

This also indicates why the front roll stiffness, due to the fact that the roll center is low, must be greater than that for the rear which has a relatively high roll center.

For conventional cars an approximate ratio of front to rear roll stiffness of about 8 to 5 gives nearly equal front and rear tire loadings in roll.

For a given front-suspension layout, the *roll center* (Fig. 6) is determined by extending, in the plane of the suspension A-frame, the line of the upper and lower arms to the instantaneous point of intersection. Another line connecting this point and the point of wheel contact at the ground intersects the centerline of the car at the roll center h'. This distance above the ground is the height of the roll center. If the suspension arms are at an angle to the plane through the centerline of the wheels, all points must be projected to that plane for true readings. The distance from the wheel to the instantaneous intersection point is the length of the swing arm.

Fig. 7 shows how the length of swing arm and the height of the roll center vary with changes of standing heights.

The length of the swing arm for suspension **A**, which has parallel and horizontal suspension arms at normal standing height, is infinite and the roll center is approximately on the ground. As the standing height decreases, the length of the swing arm decreases to approximately 75 in. at maximum compression and the height of the roll center rises approximately 1 in. On the rebound side of the stroke the point of intersection has shifted

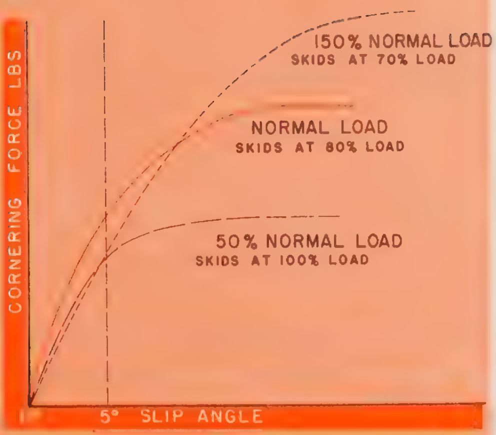

Fig. 3—Cornering ability of a tire with rated capacity at various vertical-load conditions. As the vertical tire load increases the maximum cornering ability decreases.

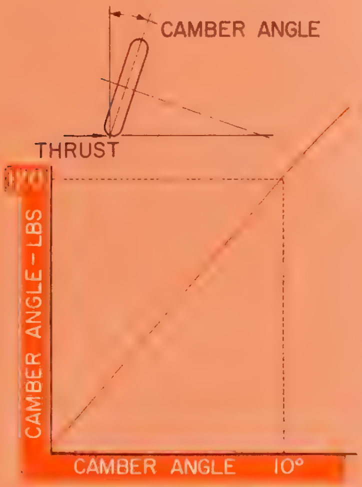

Fig. 4—The cornering ability of a tire depends, to a degree, on the camber angle. This angle produces slip angles which, in turn, produce side forces.

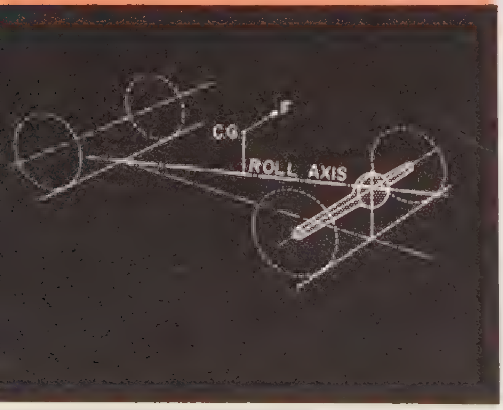

Fig. 5—The roll axis of a car is a hypothetical line connecting the front and rear roll centers. Cars having a low roll axis will roll through a greater angle than cars having a high roll axis when an applied force is exerted at the center of gravity. The height of the roll center will depend upon the type of suspension used.

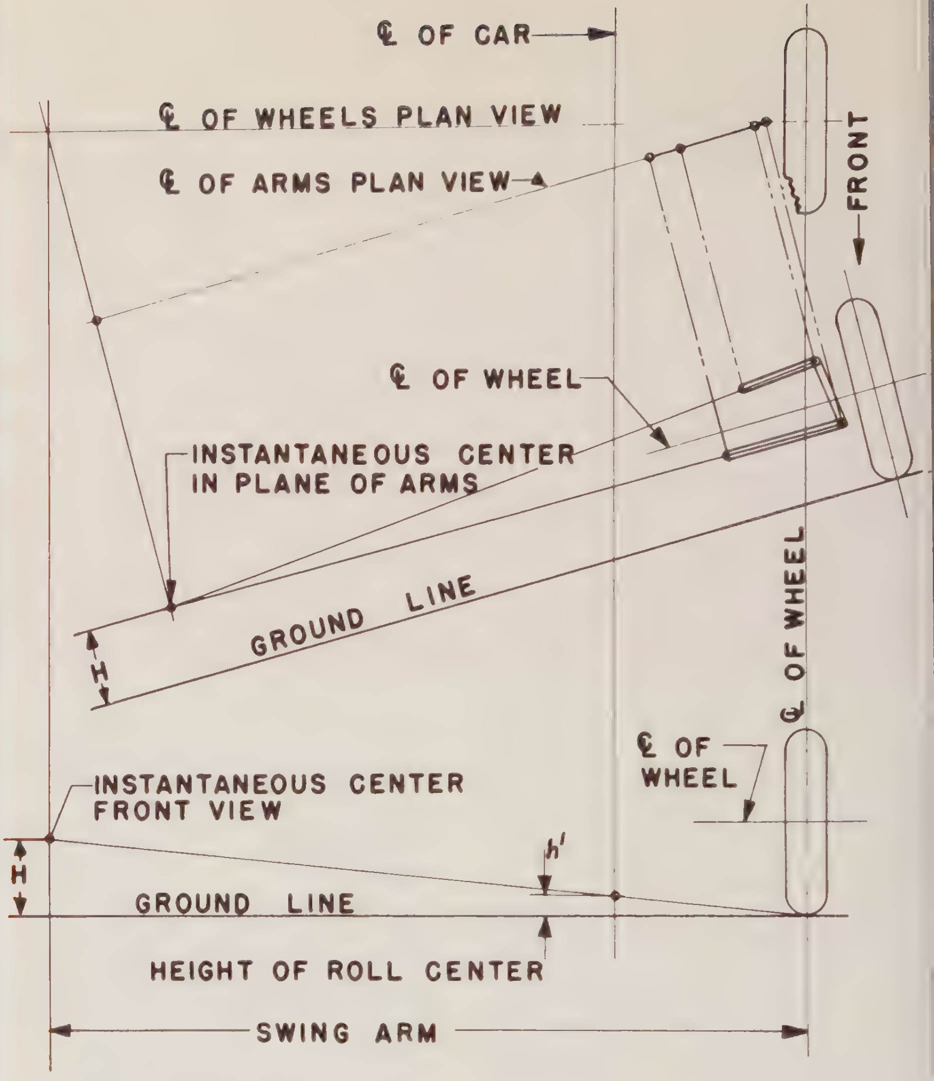

Fig. 6—Determination of roll center by descriptive geometry.

to the outside of the car, and at maximum stroke the length of the swing arm has decreased to about 50 in. with a roll center height of approximately 1½ in. To say that a suspension has *parallel* arms, means that the arms are parallel in their true view at normal standing height. They are *converging* arms when the vertical distance between the inner ends of the upper and lower suspension A-frame is less than at the steering-knuckle support.

Suspension **B**, which has converging arms, has a 130-in. swing arm and 2⅜-in. height of roll center at normal standing height. Here again, the length of the swing arm decreases to approximately 50 in. at maximum bump and shifts to the outside of the car at about ⅞-in. rebound.

Fig. 8 indicates the camber and tread change produced by the two suspension layouts. These are actual curves from 1948 model cars, as it happens.

First, consider them as they are actually plotted either from test or layout data. These curves indicate the change of camber angle with respect to compression or rebound wheel position. The curve for the car with converging arms at normal standing height changes much faster than the others; thus, in roll the wheels stand up straighter. By transposing inches deflection for degrees roll and assuming that a car rolls through an angle of four degrees, the outside wheel of car **B** with a converging suspension has a camber angle of plus 2½ degrees, as compared to approximately 3½ degrees for the car **A**. The inside wheel for car **B** has negative 3½ degrees as compared to 4¾ degrees for car **A**. Since the camber

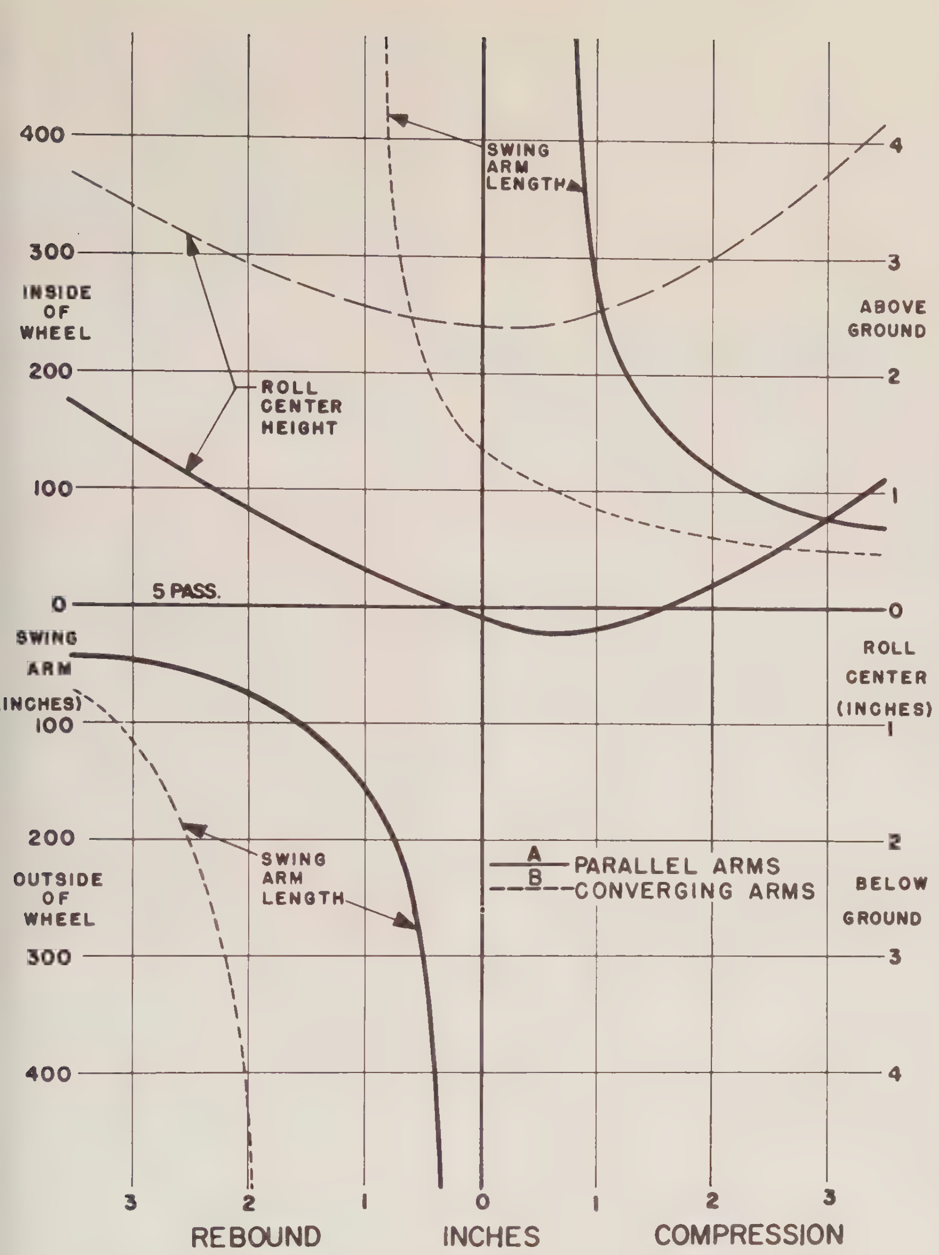

Fig. 7—Variance in swing-arm length and roll-center height with changes in standing heights.

thrust of a tire on a car in roll acts in diametrical opposition to the cornering force, the difference in camber angle between these two cars should represent approximately a ten per cent difference in cornering speed at incipient tire squeal. The difference in the tread-change curves indicates the relative heights of the roll center. Car **B** with the high roll center requires a smaller front stabilizer for proper roll balance. Its *tread-change* characteristic is manifested in a damping action for the suspension, both in ride and roll.

Referring again to the roll axis, its height at the rear of the car is at the height of the rear roll center. Determination of this point differs for different types of suspension.

For leaf-spring installation the rear roll center is at the point of intersection of a plane through the four eyes of the two springs and the vertical line at the center of the rear tread (Fig. 9). The height of the roll center is then controlled by the camber of the springs and their attachment at the axle.

A transverse track bar above the leaf spring raises this roll center by an amount which is proportional to the relative lateral stiffness of the springs and the track bar.

A coil-spring installation with a transverse track bar has its roll center at the height of the track bar on the centerline of the car. This is true because the transverse stiffness of the bar is relatively high as compared to that of the springs.

The height of the roll center at the rear of the cars of recent years falls between 8 in. and 18 in., depending on the type of suspension.

Oversteer and Understeer

What do oversteer and understeer mean in a geometric sense? This characteristic due to car roll is the increase or decrease of the front wheel steering angle, relative to that imparted to the wheels by the driver. If a given steering angle produced by the driver increases with car roll, the car steers into the curve or oversteers. Conversely, if the steering angle decreases as the car rolls and the car steers out of the curve, this is understeer. The condition is brought about by the relationship of the motion of the steering linkage and that of the suspension. If the path of the outer end of the swinging link of the steering linkage exactly matches that of the steering arm, the geometry is neutral. If the inner end of the steering link is raised or lowered, the car oversteers or understeers as the case may be.

Referring to Fig. 10, if the arc *A-A*, which is the path scribed by the steering-arm pivot, coincides with that of the steering swinging link, the geometry is neutral. Geometric oversteer results by raising the inner end or increasing the length of the swinging link. This causes the curves to mismatch in such a manner that the outside wheel in roll toes-in on compression while the inside wheel toes-out on rebound. The opposite condition results in understeer.

The old standby, the three-link equivalent system, best illustrates the method of determining the rear-axle steer as applied to a semi-elliptic spring (Fig. 11). Assuming that the spring is designed for uniform strength, it has a true circular arc shape at all loads. Under this condition the point at the center of the clamped area moves on an arc of $\frac{3}{8}(l_1 + l_2)$ radius. This point for a flat spring is approximately $3/2\ e_2$ in. below the centerline through the eyes. The rear and front lengths of the spring exclusive of the clamp are l_1 and l_2, and e_1 is the distance from the center of the main leaf to the eye centerline. This illustration as drawn

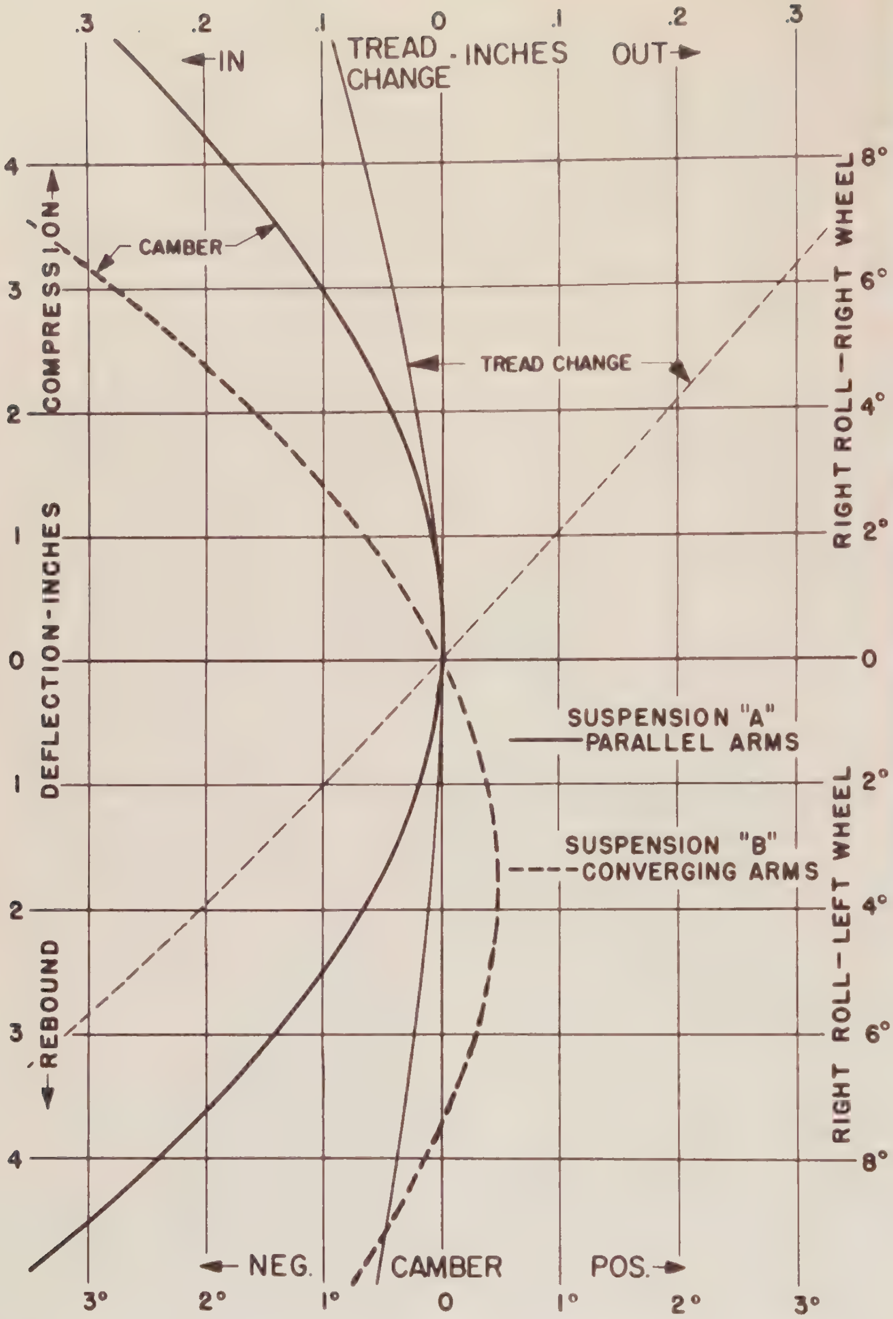

Fig. 8—Comparison of camber and tread change produced by the parallel-arm and the converging-arm systems of suspension.

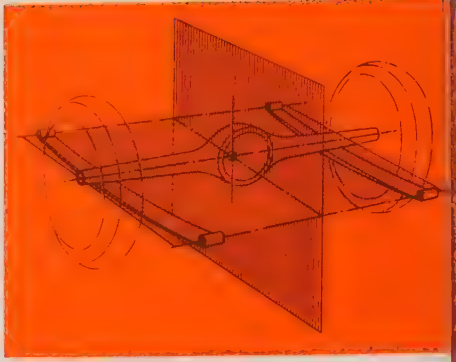

Fig. 9—The height of the rear roll center depends on whether a leaf-spring or coil-spring installation is used.

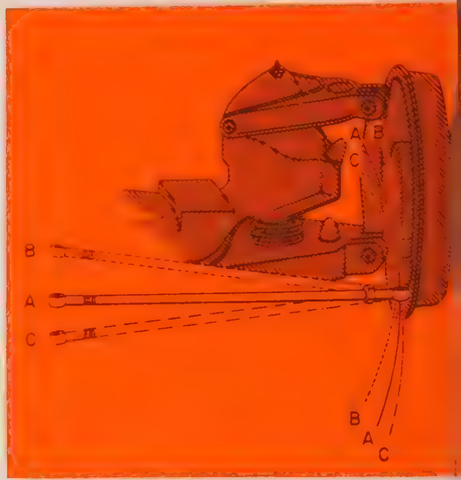

Fig. 10—Relative positions of the steering arm during conditions oversteering, understeering, and neutral. Arc *A-A* is the path scribed by the steering-arm pivot when coinciding with the steering swinging link. In this case the geometry is neutral. When the inner end of the steering swinging link is raised, as at *B*, the mismatched arc *B-B* results, which is the oversteer condition. The opposite action results in understeer *C-C*.

(Fig. 11) oversteers if the assumption is allowed that the main leaf is flat in its normal load position.

Using this to illustrate an actual installation where the car rolls to the left, then as the outside wheel is compressed, it is forced back along the line of the arc as the right wheel in rebound is pulled ahead. This causes the axle to steer to the left or in the direction of roll, and the car steers into the corner or oversteers. If in this illustration the main leaf were cambered such that its mid-point at normal load was on the fore-and-aft centerline between the eyes, the geometry would be neutral. If the same conditions prevailed, but the fore-and-aft centerline through the eyes sloped down toward the front, the geometry would be understeer.

The length *A* of the radius arm fixes the point about which the center of the spring clamp moves in parallel ride motion. The ratio of front to rear length of the spring determines this length *A*, which controls the squat and lift characteristics for starting and stopping.

The geometry of a torque tube or fixed radius arm of a coil-spring suspension is somewhat easier to determine. The wheels in roll move in a plane normal to a line, connecting the front pivot point of the suspension and the track bar at the centerline of the car. In this case the geometric link is very long; so the change of steering geometry, for the normal range of motion, is less than for a leaf-spring installation.

The geometry of a torque-tube, leaf-spring installation is more difficult to determine, as the final result is a product of the geometry and stiffness of both springs and torque tube.

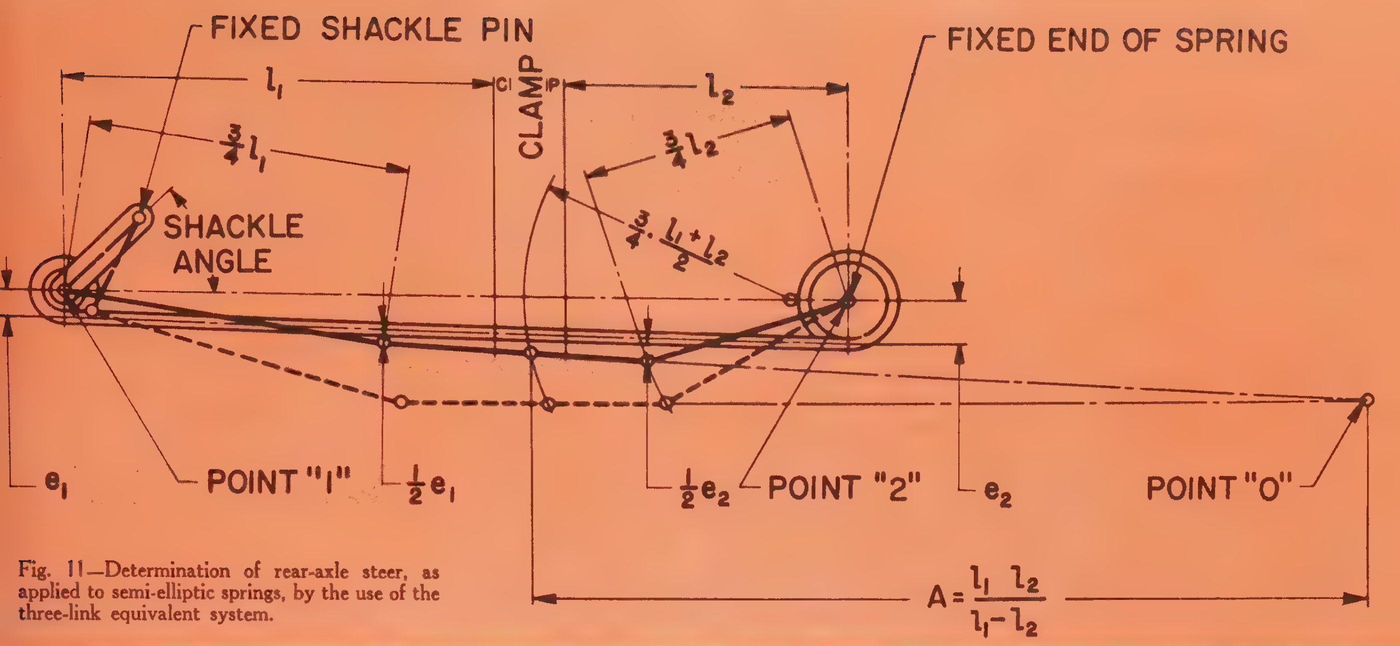

Fig. 11—Determination of rear-axle steer, as applied to semi-elliptic springs, by the use of the three-link equivalent system.

Conclusion

In designing a steering system it is mandatory that the engineer consider all the factors and then arrive at an optimum solution for a particular automobile. It is impossible to segregate any of these conditions at the exclusion of another. The interdependence and interrelation of all of the factors must be considered constantly in this work and the final result is a product of the balance achieved.

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Glossary

For paper beginning on page 8: "An Analysis of the Suspension Problems of the Automotive Vehicle."

Ackerman radius, also known as Ackerman steering, is the geometry designed into the front suspension and steering linkage to control the angular movement of both front wheels in turning.

Camber angle is the inclination of the wheel plane to the vertical. It is considered positive when the wheel leans outward at the top, negative when it leans inward.

Cornering power is the ability of an automobile to overcome the centrifugal force when going around a corner.

Oversteer is the characteristic of the geometry of the steering linkage or the rear-spring linkage of an automobile in which the wheels steer into the turn as the car rolls away from the turn from lateral force.

Roll is the angular displacement of the sprung mass about a central longitudinal axis, with respect to its static position.

Roll axis is the line joining the front and rear roll centers.

Roll center is that point in the transverse vertical plane through any pair of wheel centers and equidistant from them, at which lateral forces may be applied to the spring mass without producing an angular displacement of the spring mass.

Tread change is the change in distance between the centers of the tire contact of a pair of wheels resulting from vertical suspension displacements.

Understeer is the characteristic of the geometry of the steering linkage of an automobile in which the wheels steer out of the turn as the car rolls on its roll axis from lateral force.

Studies in Resistance Welding Yield Improvements in the Manufacture of Thin-Wall Steel Tubing

By **DONALD P. WORDEN**
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Division

High-frequency
resistance welding
increases productivity

Resistance welding is utilized in the production of thin-wall steel tubing by a number of manufacturing plants. Tubing of this type is used for refrigerator coils, radiant heating, and a great many other commercial purposes. Resistance-welded tubing is made by passing flat, steel strips through a series of rolls which form the metal into a tubular shape. A welding machine then welds the abutting edges of the metal into a continuous seam as the tubing travels from the rolls through the welder at a fairly high rate of speed. Increased demands for welded, thin-wall steel tubing have brought about the need for improved methods and additional manufacturing equipment. Studies relating to the effects of higher frequencies of applied voltage on the weld, the composition of tubing material, and various mechanical factors resulted in the development by Rochester Products Division of new welding equipment and techniques. These improvements have permitted higher tubing speed, reduced the number of new mills required in the plant, and contributed other advantages.

The manufacture of resistance-welded steel tubing for a diversity of applications is a technical area in which improvements are constantly being made. By and large, these improvements have been effected through the combined efforts of mill manufacturers and tube producers. Under this system, however, no one manufacturer realizes any great advantage over another with respect to productivity.

As one of the large producers of brazed and welded steel tubing, including refrigerator coils and tubing for radiant heating, the Rochester Products Division felt the need for additional facilities in this field. As a result, considerable thought was given to the comparative merits of the conventional method with short-range gains and the application of new methods with potential long-range gains. Decision in favor of the latter course gave impetus to a development program with the following objectives:

- Determine the factors limiting tubing-manufacturing speed in conventional equipment.
- Translate these factors to new equipment in order to raise the limits.

Appraisal of Conventional Equipment Used in Standard Mills

In order to determine the limiting factors in the use of conventional equipment, a systematic and progressive appraisal of each factor in the standard *mill* was made, beginning with the *forming section.*

In this section, a series of driven, horizontally opposed rolls (Fig. 1) convert the flat strip of material to a tubular shape with the abutted edges at the top (Fig. 2). The only requirement of this operation is to obtain a uniformly symmetrical shape possessing a smooth radius on the top portion. This may appear, on the surface, to be a simple task, but the degree of perfection required in the radius is at times difficult to attain. Fortunately, tubing speed is of minor importance in this phase of the operation. Therefore, this section of the mill was considered adequate and is not discussed further in this paper.

The *welding station,* next in sequence, comprises a rotating transformer, the secondary of which terminates in two wheel-shaped electrodes contacting the tube. An air gap of from 0.050 in. to 0.125 in., depending on wall thickness of the tubing, separates the electrodes and bisects an annular groove, referred to as the *electrode radius,* running about the circumference. A weld support or *back-up roll* positions the tube contacting the electrodes with the seam central within the air gap (Figs. 3 and 4). The frequency of the welding voltage is generally 180 cps, and is derived from a motor-driven alternator. Precise control of welding current is effected by varying alternator excitation, thereby controlling output.

Relationship of Tube Speed and Welding Voltage

It might be said of the welding operation that it is the focal point of the process where the end products of numerous operations emerge as one. All preparatory operations are brought to fruition or failure, depending on the conditions existing in a distance not greater than 0.050 in. (Fig. 5). Because of this relatively short distance, referred to as the *unit welding distance,* tube speed and frequency of welding voltage bear a particular relationship to each other.

From tests, for example, it has been determined that, with a frequency of 180 cycles and a tube wall thickness of 0.026 in., the maximum speed is approximately 88 ft per min with a power input of 280 w per ft per min. Increased speed produces minute cyclic discontinuities or *voids,* sometimes referred to as *stitching,* in the weld which weaken it (Fig. 6). The distance between these voids was found to be 0.048 in., and this distance was found to increase as line speed was increased. For example, at 100 ft per min, the voids occur at 0.055-in. intervals. Power can be increased, of course, but a large bead and no appreciable effect on the voids are the results. Since the objective of the study was to increase speed, it was necessary, therefore, to eliminate the voids.

Interpretation of Results

A study of the basic facts resulted in the following interpretation. All heating

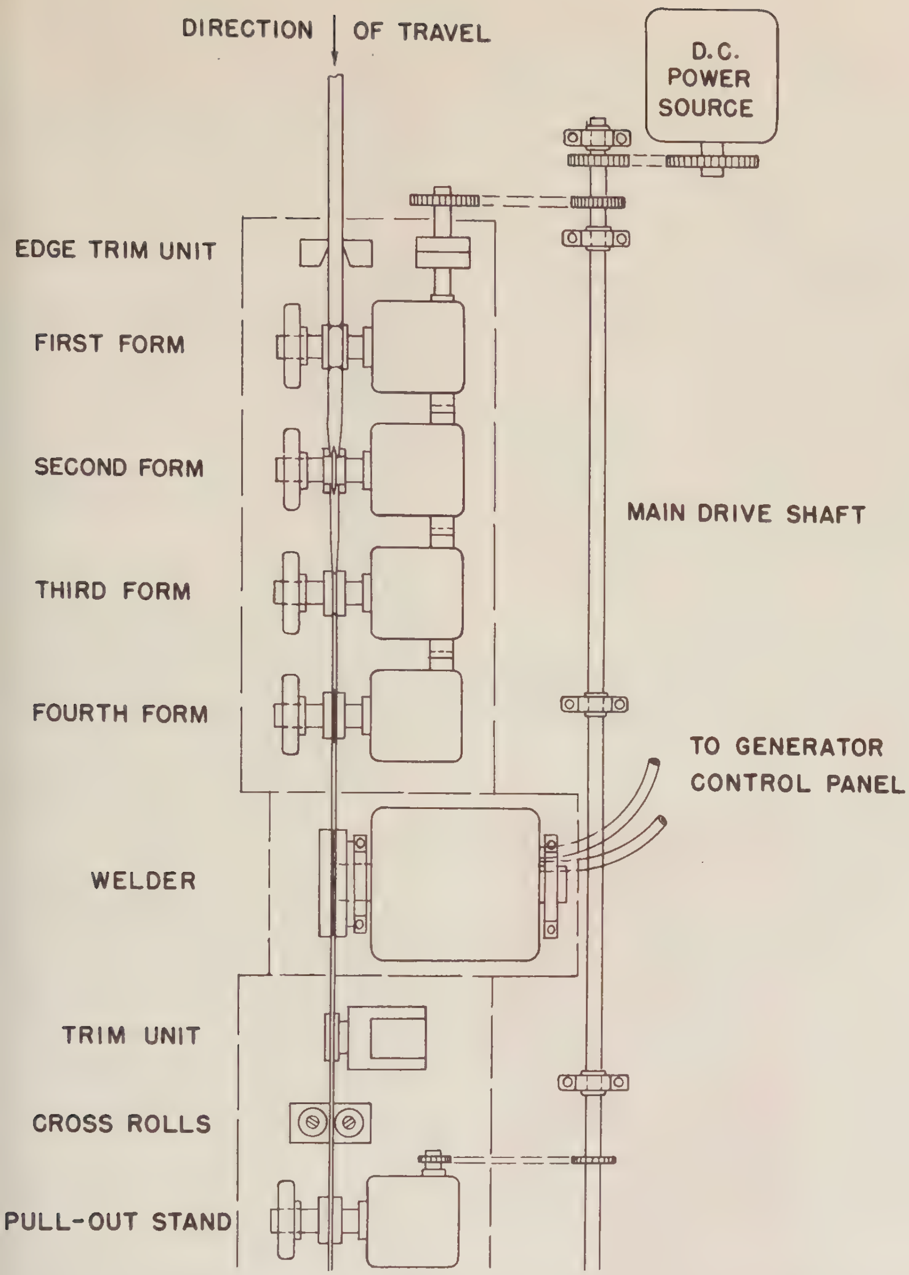

Fig. 1—Diagram of principal equipment used in the production of resistance-welded, thin-wall steel tubing. A flat strip enters a line-up of forming mills (top) which form the metal into a tubular shape with the abutting edges of the strip at the top. Rotary electrodes on the resistance-welding unit weld the edges in a continuous seam.

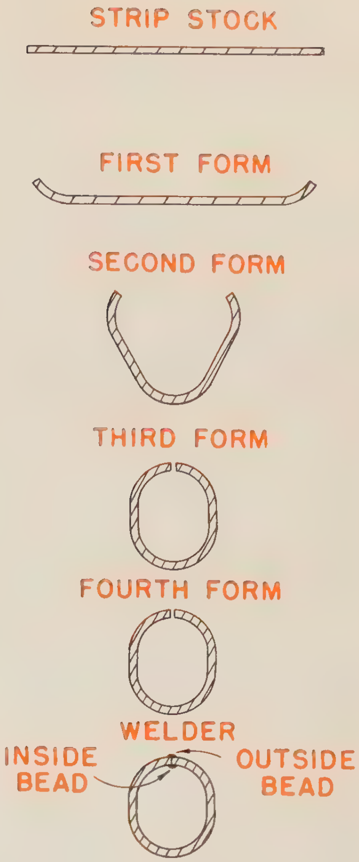

Fig. 2—Steps in the formation of tubing at the various stages of the operation. In making the study of this manufacturing process, it was found that the forming operations already in use were adequate to handle a faster travel of the steel through the rolls. Attention then was given to improving the resistance-welding operation.

is effected through the conversion of I^2R energy in time T. Current I is alternating at a frequency of 180 cps, creating a positive and negative half-wave in each cycle. These half-waves are substantially sinusoidal in shape and, for purposes of illustration, are represented as positive in direction (Fig. 7a). Note that for a constant resistance power varies from zero to twice the effective or *rms* value in each half-cycle (Fig. 7b). Since the seam is not a constant resistance because of its temperature coefficient of resistance and also because of thermal inertia and conductivity, the welding effect is discontinuous under certain circumstances as Fig. 8 shows. At 88 ft per min, for example, the tube is moving 17.6 in. per sec, and any point of the seam travels 0.048 in. in 1/360 sec, or the time of a half-cycle. Since 0.048 in. equals the unit welding distance *uwd* any increment of the seam is subjected only once to all instantaneous welding voltages comprising a half-cycle. The temperature rise experienced by an increment entering uwd at time T_1 follows generally the temperature curve shown during the period T_1 to $T_1 + 1/360$ *sec.*

It can be seen from this curve (Fig. 8) that additional energy is required to raise the temperature to the minimum satisfactory welding temperature. However, since this increment has completed its passage through uwd, no additional energy is available, creating a void.

Referring to the curve T_2, it is seen that an increment starting at time T_2 experiences an initial temperature rise in a portion of the first half-cycle, and because of thermal conduction from the preceding adjacent increment, continues to rise in temperature even at current zero. Further temperature rise is effected in the interval $T_1 + 1/360$ *sec* to $T_2 + 1/360$ *sec* since the voltage is rising. The increasing voltage causes sufficient current to flow, despite the higher resistance (due to temperature), to reach welding temperature.

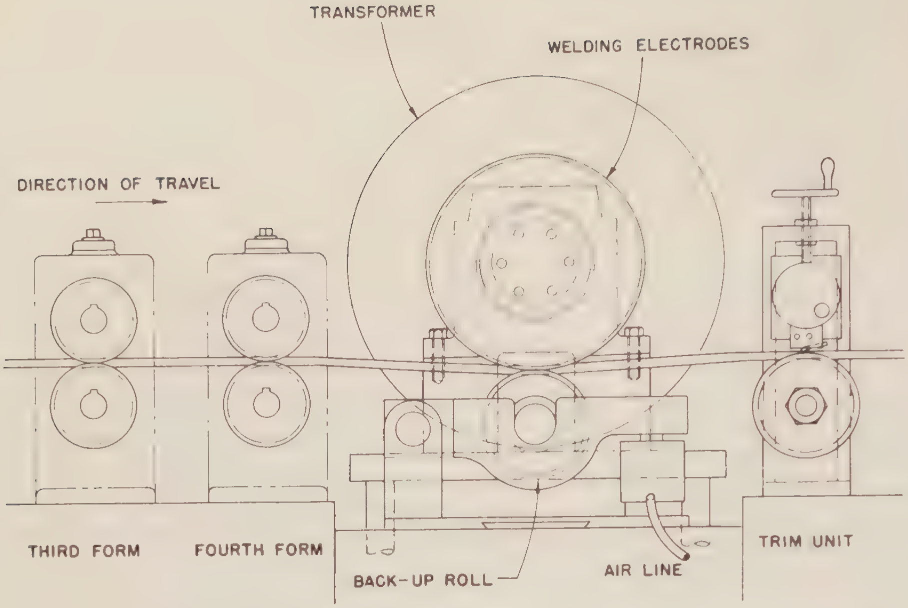

Fig. 3—The focal point of the process is the welding operation. This diagram shows how the tubing passes from the forming rolls directly to the rotating electrodes and back-up roll of the resistance-welding machine.

The curve starting at time T_3 is similar in behavior but reaches the highest final temperature because of the higher voltage at $T_3 + 1/360$ *sec*. These curves represent only a graphical presentation of the phenomena and should not be considered as exact. However, under the stated conditions they may serve all practical purposes.

Since the non-weld is caused by the coincidence of zero current and the completion of movement through uwd, it becomes necessary to preclude the possibility of the coincidence. This can be accomplished by using direct current or by increasing the frequency. In the latter case, for example, if the frequency were doubled, stitching would not be observed until the tube speed had been doubled.

Transformer Design Studies

An analysis of the possible use of direct current then was made and was ruled out because of equipment costs. In addition, direct current in voltages of from two to six volts and currents of from 10,000 to 30,000 amp is not easily obtained or readily conducted through rotating contacts. The selection of a suitable frequency also presented a number of ramifications; however, 960 cycles appeared to offer considerable advantage, particularly the possibility of increasing line speed five times.

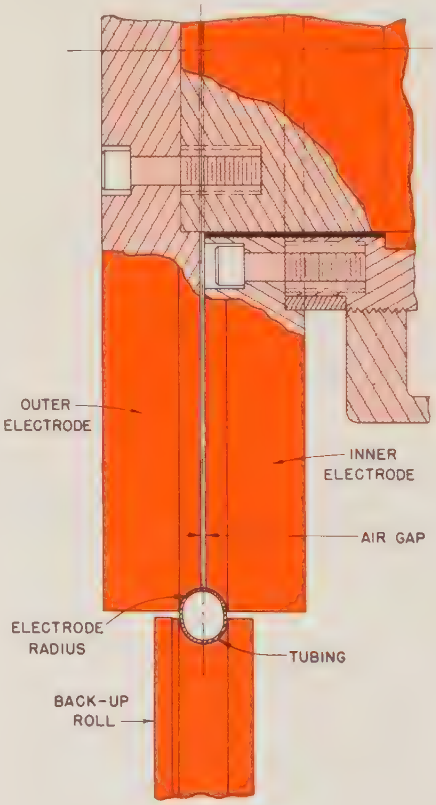

Fig. 4—The electrode-radius contact, illustrated in this sectional view of the welder and tube, is sometimes difficult to control perfectly. Control of the contact, however, is not affected significantly by tubing speed. The air gap between the rotating electrodes may vary from 0.050 in. to 0.125 in., depending upon the thickness of the tubing material being used.

Relationship of Leakage Reactance and Voltage

In order to obtain actual transformer-design data, a 400-v, 25-kva, 120-turn transformer was constructed and installed using the mechanical parts from an existing 180-cycle transformer. Because of high *leakage reactance*, calculated at 58 per cent, the primary voltage had to be increased to 700 v in order to weld.

Leakage reactance may be described as the magnetic flux in any transformer which does not link both the primary and secondary windings. Its effect is to require more primary voltage to produce the required secondary voltage than would be indicated by the primary-turns ratio times secondary volts. Normal power transformers exhibit a negligible amount—due to the fact that, as primary and secondary ratios become higher and secondary currents increase, it becomes increasingly difficult to adequately insulate the primary from the secondary without creating air spaces which provide high-leakage flux areas. A mechanical analogy might be the presence of air bubbles in a fluid coupling.

While some work was performed using the experimental transformer described above, the high-leakage reactance caused the welder to be load sensitive—that is, changes in load current caused large voltage changes. As a result, power-factor correction was found to be a necessity, and it was evident that welding with a voltage of 960 cps was impractical unless leakage reactance could be reduced substantially.

A second transformer then was designed and built which embodied factors designed to reduce the leakage reactance. This unit, a 50-kva, 85-turn, 400-v transformer had a calculated leakage reactance of 17 per cent, which a short circuit test later revealed to be actually 23 per cent. Special attention was given to the iron used in the core and five-mill, grain-oriented steel was used with a calculated flux density of 30 kilo lines per in.^{2}

The following formula identifies the principal factors which may be changed to reduce leakage—namely, turns per unit magnetic length and the space between primary and secondary windings. Note that this formula is an empirical expression and, while it has been found useful in designing 960-cycle and 420-cycle transformers, it may not be suffi-

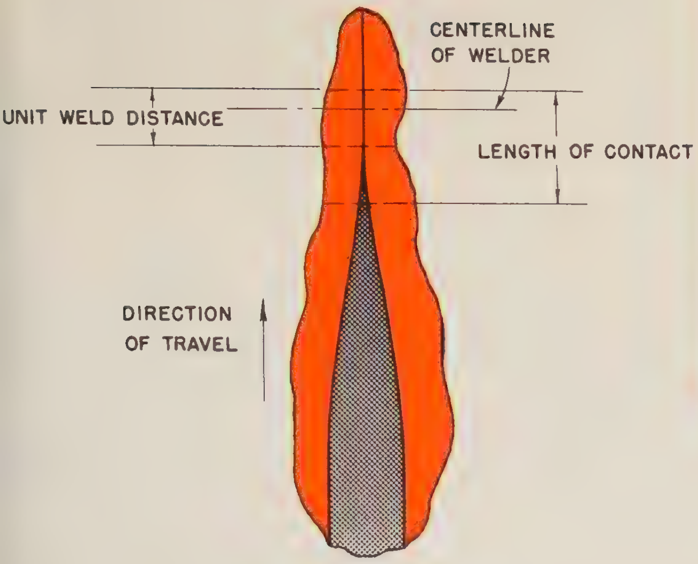

Fig. 5—The critical part of the tubing manufacturing process is the action which takes place in the *unit weld distance*, shown in this top view of the weld area. The unit weld distance does not exceed 0.050 in. Because of this short distance, tubing speed and the frequency of welding voltage have a particular relationship to each other.

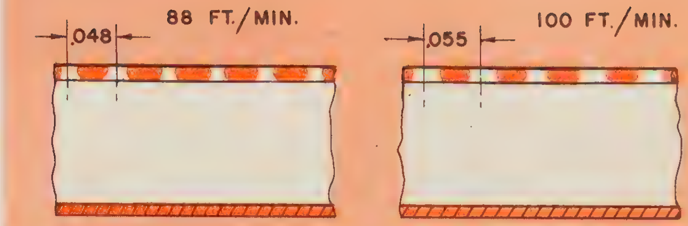

Fig. 6—This sectional view of the weld illustrates how the distance between voids is affected by increasing the speed of the tube through the welder, while maintaining the same frequency. Engineers studied methods of utilizing either direct current or higher frequencies to eliminate these voids as higher tubing speeds were sought.

ciently accurate for application to other design areas.

$$X_L = (21.5Ft_p^2/L_m10^8)(d_p+d_s/3)+S(l_p+l_s/2)$$

where

X_L = leakage reactance in ohms
t_p = turns on primary
d_p = thickness of primary winding
d_s = thickness of secondary winding-in.
S = space between windings
l_p = length of mean turn on primary
l_s = length of mean turn on secondary
L_m = length of magnetic circuit
F = frequency in cps.

Performance Characteristics

Some very interesting facts were obtained using this transformer; for instance, there was no evidence of stitching at 400 ft per min. Power requirements were found to be 125 w per ft per min. A much-reduced bead size was obtained; in fact, samples were made without employing any flash removal as is required in conventional equipment (Fig. 2, last form). Power-factor correction was still necessary, although load sensitivity no longer caused difficulties. Tubing wall thicknesses greater than 0.035 in. presented a number of problems, but these were minimized by increasing the air gap. Fortunately, the normal operating variables, which sometimes cause trouble in conventional welding methods, presented no problems in this new method. Based on laboratory tests, the high-speed operation seemed to be less difficult and more successful from a welding standpoint than its predecessor.

From Fig. 9, it is seen that 14 kw are required to weld at 50 ft per min, while at 400 ft per min, 50 kw are required. This is equivalent to 280 and 125 w per ft per min, respectively. This decided increase in efficiency is the result of the high speed and, consequently, there is less heat conducted away from the seam to adjacent areas. As speed increases, the time during which heat is conducted away from the weld decreases, in turn decreasing the temperature rise of the adjacent area. Because of this factor, the resistance of the adjacent area is less, reducing the energy loss in this section due to I^2R heating. These two factors stabilize at some point at any given speed, and the curves indicate that, over the range explored, weld power increases approximately one-half as rapidly as tube speed.

A group of several welders based on the above design subsequently were installed and now they form the nucleus of the high-speed, thin-wall tube mills at Rochester Products Division. While usable on walls heavier than 0.035 in., these welders are less efficient for heavier walls. For this reason, and also because Roch-

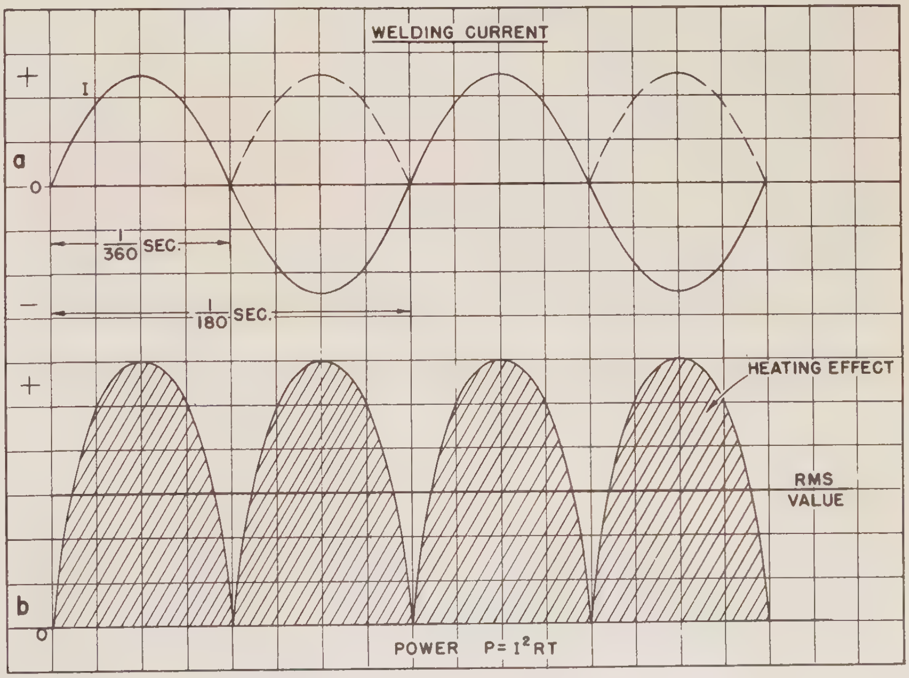

Fig. 7—(a) Approximation of the welding current curve. For purposes of illustration, the half-waves may be represented as positive in direction. (b) For a constant resistance, power varies from zero to twice the effective, or rms, value in each half-cycle.

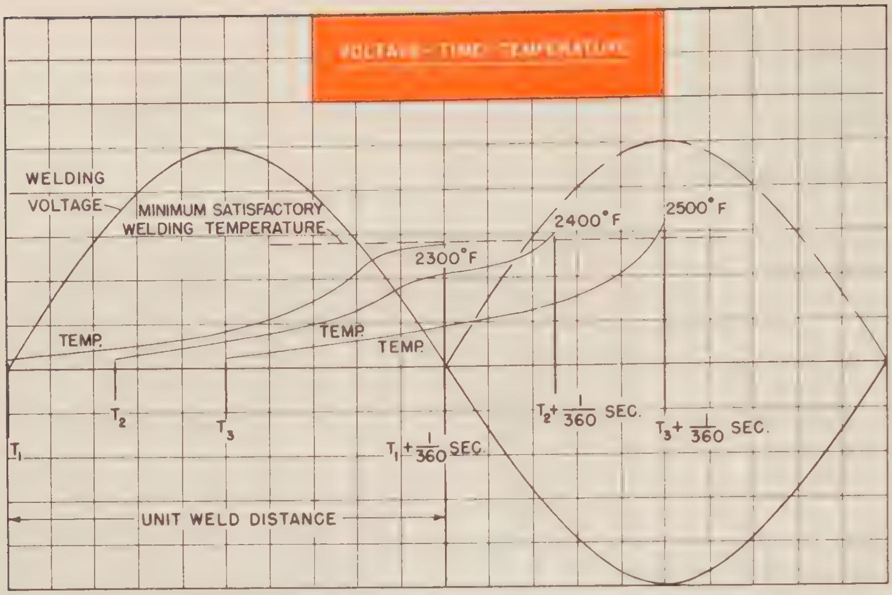

Fig. 8—Voltage-time-temperature characteristics of the welder. These curves show a graphical representation of the phenomena and, while not exact, they are satisfactory for this study under the stated conditions.

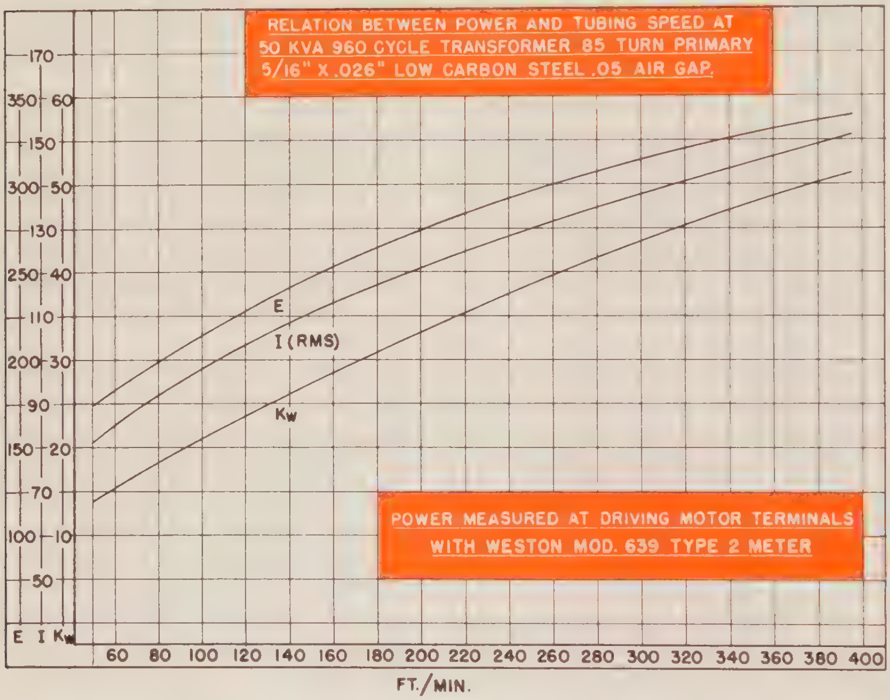

Fig. 9—This curve shows the relation between power and tubing speed using a 50-kva, 960-cps transformer, 85-turn primary, and $\frac{5}{16}$-in. by 0.026-in. low-carbon steel with an air gap of 0.05 in.

ester Products Division produces tubing up to 0.070 in. wall, a 100-kva, 420-cycle transformer was developed which embodied all the factors found to be important on the 960-cycle unit. This served the dual purpose of permitting good speed on both light- and heavy-wall tubing.

Material Requirements for Weld Quality

While the foregoing discussion has been concerned principally with the welding method, the necessity to explore the field of tubing-material composition also was recognized. Items such as the deoxidizing procedure and the materials used have established beyond all doubt, under observation and statistical analysis, that a fully aluminum-killed steel is the most satisfactory material. Scrap figures for the non-killed steel are approximately twice those of killed steel. Further exploration in this field may reveal the importance of maintaining a balance of constituents in some prescribed manner, perhaps in percentages currently considered too small to be of any consequence.

Effect of Edge Conditioning on Weld Quality

Another factor having great bearing on weld quality is that of *edge conditioning*, which does not mean simply the removal of oxides. From tests conducted with several different types of conditioning tools, it was learned that the surface obtained from very sharp paring-type tools produced the best results, even permitting, in some cases, a reduction of welding temperatures without adversely affecting the weld. All carbon steels were found to be easier to weld using this method of edge conditioning. The explanation seems to lie in the pattern of the exposed edge grains—if smooth and not deformed, the edges appear to be more amenable to welding. This fact can be of considerable importance in any type of difficult welding operation.

Conclusion

In drawing conclusions, it should be borne in mind that, while a particular application of resistance welding has been under discussion, it is essentially seam welding, and is, therefore, applicable to any seam-welding process. It would seem reasonable to state that high-frequency resistance welding has much to offer in the areas of productivity and power usage. Additionally, it is also important to consider the nature of the surfaces to be joined, not entirely in terms of a superficial surface but also as a homogeneous continuity of grain structure and pattern.

Electrical problems involving high current at high frequencies appear to be capable of solution. The returns of capital investment and savings in operator unit costs are factors which prove the value of believing in the existence of and searching for the better way.

Acknowledgment

Appreciation is expressed to Messrs. R. I. Hahn, Elmer Olson, J. W. Armstrong, R. W. Spears, E. A. Kehoe, and H. H. Dietrich for helpful suggestions and criticisms rendered in the preparation of this paper.

Chemical Engineering Moves Alongside Mechanical Engineering In New Speedometer Design

By RALPH O. HELGEBY
AC Spark Plug Division

Molded-nylon worms, gears test-operated 300,000 miles without apparent wear

Gear designing conventionally has been in the field of the mechanical engineer cooperating with the metallurgical engineer. Today, chemical engineering is finding increasing use in geared mechanisms because of the productiveness of research on application of molded plastic materials. AC Spark Plug Division has a continuing study program aimed toward the use of molded nylon parts for certain applications where quietness is a requirement. When study results indicate advantages of molded nylon over metal parts, nylon makes another gain in usage, as in the new speedometer developed for the Buick Super and Roadmaster 1954 models.

Continuing research into moldability and durability of nylon has resulted in the first production use of molded worms and gears for some AC Spark Plug Division 1954 speedometers. These parts (Fig. 1) are built into the new speedometer for the Super and Roadmaster models of 1954 Buicks. The speedometer has been given the trade name Redliner.

Advantages which may be claimed for molded nylon parts over metal equivalents for this speedometer application include greater ease of manufacture, greater durability, silence of operation, resistance to corrosion, and lighter weight.

A very desirable advantage of nylon gears for speedometer application is the self-lubricating quality which eliminates the need for periodical oiling and greasing. As an indication of durability, odometer tests during the product-development stage showed that a nylon worm gear exhibited no significant wear after an equivalent of 300,000 miles of operation.

As some speedometers are calibrated in miles and others in kilometers it is necessary in the assembly operation that workmen differentiate between similar but not identical parts. With nylon it is possible to use different-colored materials to aid correct assembly. Red parts are used for odometer gears in instruments calibrated in kilometers and white for those calibrated in miles. Nylon parts have proved to have sufficient flexibility to compensate for any slight warpage, making them self-aligning. The elastic property of molded nylon works to advantage in fitting parts to shafts. A nylon washer forced over the tapered section of the shaft snaps into its groove to serve as a retainer in the completed assembly.

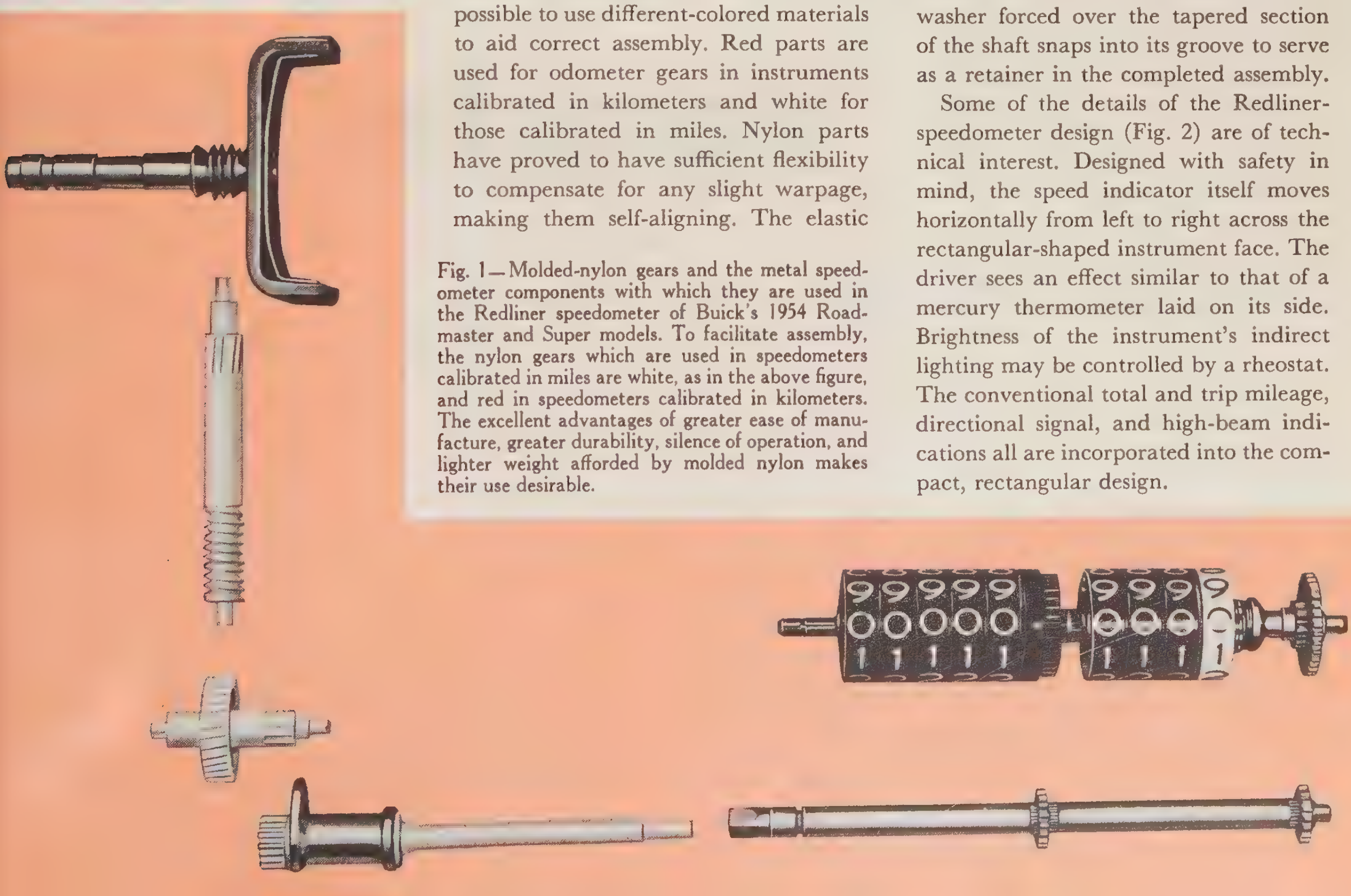

Fig. 1—Molded-nylon gears and the metal speedometer components with which they are used in the Redliner speedometer of Buick's 1954 Roadmaster and Super models. To facilitate assembly, the nylon gears which are used in speedometers calibrated in miles are white, as in the above figure, and red in speedometers calibrated in kilometers. The excellent advantages of greater ease of manufacture, greater durability, silence of operation, and lighter weight afforded by molded nylon makes their use desirable.

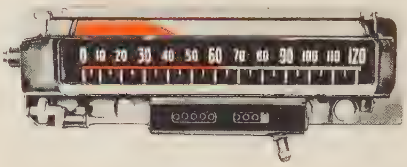

Fig. 2—Redliner speedometer on 1954 Super and Roadmaster Buicks represents the only major technical change in more than 40 years of speedometer development. The unique feature is the continuous, horizontal, ⅛-in. speed indicator which rises with increasing speed much as does a mercury thermometer with elevating temperatures.

Some of the details of the Redliner-speedometer design (Fig. 2) are of technical interest. Designed with safety in mind, the speed indicator itself moves horizontally from left to right across the rectangular-shaped instrument face. The driver sees an effect similar to that of a mercury thermometer laid on its side. Brightness of the instrument's indirect lighting may be controlled by a rheostat. The conventional total and trip mileage, directional signal, and high-beam indications all are incorporated into the compact, rectangular design.

How Engineers Select Metals for Oil-Film Bearing Applications

By E. B. ETCHELLS
Chevrolet Motor Division

Material specifications indicate how bearing requirements can be met

Whether a bearing functions properly during its operation depends, to a great extent, on the correct selection of the bearing metal. The requirements which a bearing metal must meet are varied and the engineer faces a problem of selecting the right metal from the many that are available as bearing materials. The selection would be simplified if it were possible to find a metal which would meet all bearing requirements, but one desirable property too often is gained by the loss of another. A knowledge, therefore, of what requirements a bearing metal must meet and what properties the available metals have, is essential. The specific metal selected is one which the engineer believes possesses the optimum compromise of the qualities required for the particular task.

THE selection of a metal to be used in plain oil-film or boundary-film bearing applications is dependent upon a number of requirements. Among them are:

- Score resistance
- Deformability
- Fatigue strength
- Corrosion resistance
- Cost.

The selection is not an easy one, however, since no one metal is available at present which is capable of meeting all the varied applications to which bearings are subjected. For one application fatigue strength may be the controlling requirement, whereas another application may require the very best score resistance with maximum corrosion resistance. The final selection of a bearing metal usually depends, to a great extent, on experience, judgment, and compromise. As will be shown, the above bearing requirements are, in some respects, interrelated and the best choice for a bearing metal is made by recognizing first what the bearing requirements are and then selecting a commercial alloy having these qualities.

Research is being done continuously on perfecting bearing materials. The results of work that has been done have led to the conviction that a bearing metal will function properly during operation if it has a high endurance limit and load-carrying capacity and if a soft, readily conformable metal can be plated in a thin layer on the working surface.

Bearing Requirements

No order of importance is suggested by the following individually different requirements of a bearing. They all have their place in the selection of a metal to be used and in the design of the bearing itself.

Score Resistance

The score resistance, or anti-seizure characteristic, of metals used for bearings is often an important requirement. Scoring should not be confused with cutting or grooving of the metal by dirt or other foreign material. Most bearings are designed to run on oil films, but metal-to-metal contact may exist between the journal and the bearing due to starting, stopping, deflection, and heavy loads. Bearings also are designed to operate continuously under partial or boundary-film conditions which produce rubbing contact at the surfaces. If the score resistance is not sufficiently high, the bearing metal will score, or ultimately seize, if severe enough operating conditions exist.

Of the many bearing metals available, the white metals are used where score resistance is a prime requirement. The white metals include the tin-base alloys and the lead-base alloys, commonly called babbitts. Table I shows the relative order of common bearing metals in

	COPPER	ZINC	TIN	LEAD	ORDER OF SCORE RESISTANCE	ORDER OF INHERENT HARDNESS OR STRENGTH	SUGGESTED APPLICATION
BRASS—BRONZE	85-90 (T) 86	Fe-2 Fe-2	Al-4-10 Al-4	— —	8	1	Very poor anti-score qual Used in minor locations
	60-90 (T) 90	10-40. 9	— —	0-2 ½	7	2	Same as above Used with hypoid-gear o
	85-90 (T) 88	½-3 2	7-10 10	0-5 —	6	3	For heavily loaded* pist pins and similar motio where surface speed* very low
	80-90 (T) 88 (T) 80	0-5 4 —	3-10 4 10	5-10 4 10	5	4	Average bushing materia for low-speed, small-dian eter shafts
	70-75 (T) 72	— —	4-10 4	20-25 20	4	5	For moderate-speed bus ings and where lubrication not well maintained
Aluminum alloys					3	6	For heavily loaded mode ate-speed bearings
Copper-leads					2	7	For heavily loaded hig speed bearings
White-metal alloys (Cadmium and Babbitts)					1	8	Low to moderately loade low to high-speed bearing where dirt and deflectio are present

(T) Typical analysis

*Conditions of load and speed	Load—psi	Speed—ft/sec
Low	1,000 and under	up to 5-10
Moderate	up to 2,000	up to 15-20
High	over 3,000	over 30

Table I—Summary of score resistance and strength of common bearing metals showing that improv score-resistance properties are obtained at the expense of hardness and strength.

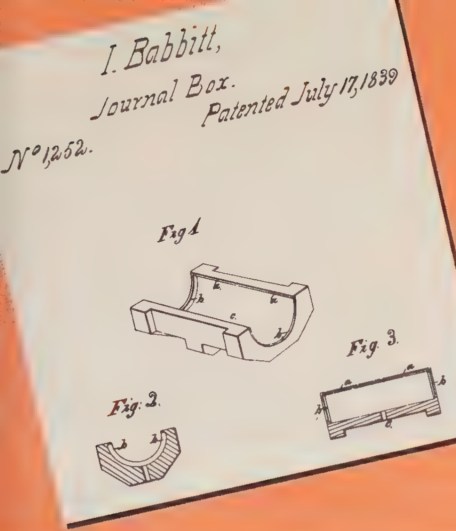

Fig. 1—Patent granted to Isaac Babbitt for a journal box containing an alloy of tin, antimony, copper, and lead for use as a plain bearing liner.

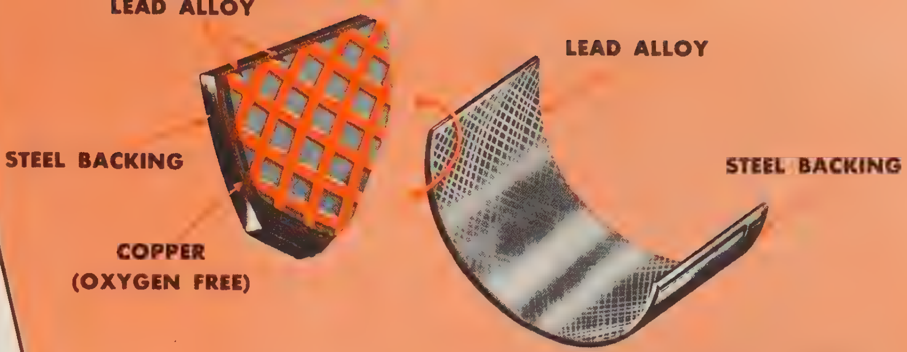

Fig. 2—Improved score-resistance properties are obtained by the use of a grid bearing. Aluminum, silver, and copper-alloy bearing materials are indented with a fine grid pattern and then filled with lead alloy.

regard to score-resistance tendencies. It can be seen that improved resistance to scoring is obtained at the expense of hardness and strength. A general classification, as listed in this table, does not allow the inclusion of special bearing metals, such as the tri-metal types of plain bearings.

Isaac Babbitt, in 1839, obtained a patent on a journal box for use as a plain bearing liner (Fig. 1). Since then, tin-base, white-metal alloys have been used with satisfactory results in machines where speeds and loads are light or at most fairly heavy. Their chief weakness, in cyclic-loaded bearings, is low fatigue life.

The aluminum alloys, as well as silver and copper, can be made to have improved score resistance by being indented with a fine grid pattern and filled with lead alloy (Fig. 2), or simply overplated with tin or lead alloy. When this is done, their score-resistance properties are nearly equivalent to the white metals.

Deformability

The ability of a bearing to yield to deformation without failure during its operation is highly important. For a bearing to have good deformability properties, it should have good conformability and embedability characteristics.

When loads are applied to a structure the bearings or journals deflect, often producing edge contact. If a bearing metal which is conformable is selected for the design, an adjustment is made without producing high temperatures that lead to a burned-out or fatigued bearing.

The embedability characteristic is important when dirt enters the clearance space, where it must embed in the bearing metal or cut a groove around the shaft and bearing. Silica (dust, core sand) or metal particles cause wear, particularly at low speeds, and overheating of the bearings at high speeds with hard metals.

Where dirt conditions are uncontrollable, white metals are preferred as the bearing metal, even though such a compromise results in a lowering of a highly desirable bearing requirement—fatigue life. When copper-lead, bronze, or aluminum alloys are used as the bearing metal, it is good practice to harden the journals in order to reduce the wear rate.

Frequently, the ability to embed when dirt is present and to conform when distortion is present, are treated as separate characteristics. In practice, a material responds about equally to each of these influences. Table II shows this characteristic as deformability. The results of relative embedability tests on a number of different commercial bearing materials with abrasive-containing lubricants are summarized in Table III. The most striking fact is the beneficial effect of the lead-base babbitt overlays. This is seen by comparing identical materials with

	ORDER OF FATIGUE STRENGTH	APPROXIMATE MAXIMUM LOAD, psi	ORDER OF DEFORMABILITY
Bronzes	1	10,000	7
Copper-lead with tin or silver	2	3,000-4,000	6
Thin babbitt overlays (0.003 in. or less)	3	2,000-4,000	5
Aluminum alloys	4	2,000-3,000	4
Copper-lead	5	1,500-2,500	3
Cadmium alloys	6	1,200-1,500	2
Lead and tin-base babbitts	7	800-1,500	1

Table II—Fatigue strength and deformability of bearing metals. Metals having good deformability requirements do not have good fatigue strength and load-carrying abilities.

Table III—(Right) Results of embedability tests on commercial bearing metals with abrasive-containing lubricants. Embedability improvement results when thin overlays are used.

NO.	MATERIALS	RATING
1	Thick babbitt (0.032 in. thick)	124
2	Durex 100A	100
3	Copper (oxygen-free)	0.5
4	Gridded copper (48 pitch)	32
5	Silver (oxygen-free)	0.7
6	Copper + 0.0008 in. Pb-Sn alloy	50
7	Copper-lead (60 Cu, 40 Pb)	7.5
8	Copper-lead (65 Cu, 35 Pb)	5.5
9	Copper-lead (70 Cu, 30 Pb)	5.0
10	Copper-lead-tin (75 Cu, 24.5 Pb, 0.25 Sn)	4.0
11	Copper-lead-tin + 0.001 in. Pb-Sn alloy	69
12	Aluminum (95 Al, 4 Si, 1 Cd)	10
13	Aluminum + 0.0008 in. Pb-Sn alloy	68

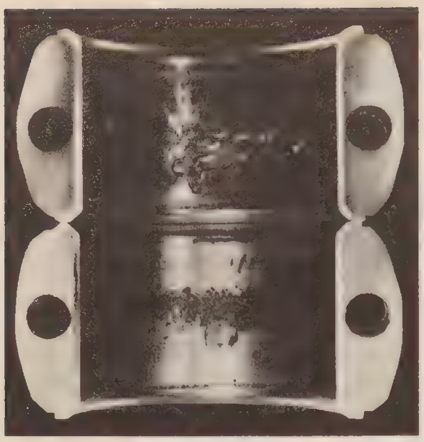

Fig. 3—Fatigue in a babbitt bearing starts as small cracks at the surface of the bearing and works down to the bonding material.

CORROSION RESISTANCE OF BEARING METALS

NON-CORRODIBLE

- Aluminum alloys
- Tin-base babbitt
- Lead-base babbitt (properly alloyed)
- Cadmium-indium alloys
- Bronzes (low lead)

INTERMEDIATE

- Bronzes (high lead)
- Copper-lead
- Alkali-hardened lead
- Silver (attacked by sulphur under certain conditions)

CORRODIBLE

- Cadmium alloys

Table IV—Corrosion resistance of bearing metals. The intermediate and corrodible alloys may reverse their activity in the presence of certain lubricants.

APPROXIMATE ORDER OF INCREASING COST

- Bronze bushings
- Lead-base babbitt
- Tin-base babbitt
- Sintered copper—Nickel filled with lead babbitt
- Aluminum alloys (solid)
- Cadmium alloys
- Copper-lead
- Copper-lead with thin overlay
- Aluminum alloy with thin overlay
- Silver with thin overlay

Table V—Together with performance characteristics, the engineer must consider the cost of bearing metals. This table shows the approximate order of increasing cost of metals commonly used for bearings.

and without overlay, such as items 3 and 6, 10 and 11, 12 and 13. It can be seen that a relative embedability or dirt-tolerance improvement of from 10 to 100 times may be had, depending upon the thickness of the overlay and the character of the basic bearing metal under the steel backing.

Fatigue Strength

Fatigue strength is important for bearings subjected to alternating loads or rotating loads. Well-known examples are the connecting-rod and main bearings of internal-combustion engines, which are subjected to rotating loads, and piston-pin bushings, which are subjected to alternating loads. Bearing failure starts in the form of small cracks at the surface of the bearing which work down to the bonding material where they progress parallel to the backing (Fig. 3). When a large enough portion of the bearing surface has fatigued, the oil-film conditions deteriorate to the point where failure by overheating quickly follows. Such failures should not be confused with those resulting from poor workmanship giving bad bond, when the difficulty shows up very early and usually can be identified by no bonding material on the backing metal.

The operating conditions, especially time and temperature, design of the bearing housing, and the amount of journal flexure have so much influence that it is difficult to state specific loads. In Table II, however, a guide to the maximum load is given.

The methods and techniques of manufacturing metals for plain bearings affect their fatigue strength. Performance of the white metals as bearing metals has been improved greatly by precision manufacturing to obtain thin overlays on a steel backing. The fatigue strength of aluminum alloys attain their highest value when securely bonded to a steel back. Long life, however, also can be found with solid aluminum-alloy bearings when the shells can be made thick and the temperature rise in the steel housing is not sufficient to cause permanent set.

The use of silver as a specialized bearing material was given impetus during World War II. It is widely used in aircraft engines because of its high fatigue strength, even under the most severe conditions. The aluminum alloy, silver, and some copper-lead bearings are used with a thin overlay (0.002 in. thickness or less) of lead-base white metal to aid in the *breaking in* process and to provide more tolerance to dirt and journal imperfections.

Corrosion Resistance

Bearing metals that are unalloyed are subject to corrosion by lubricating oils containing acids or which become acidic through oxidation (Fig. 4). Copper, lead, cadmium, and silver are especially prone to corrosion. Fatigue will result in the bearing metal if corrosion becomes excessive.

Corrosion of copper by sulphur can be greatly reduced by alloying copper with zinc, but only with a loss of anti-friction or anti-seizure properties, as seen in Table I. Lead-base alloys containing over 3 per cent tin, or not less than 1 per cent tin and suitable amounts of antimony, arsenic, or indium, can be protected from acidic lubricants. Cadmium bearings can be protected by very small amounts of indium.

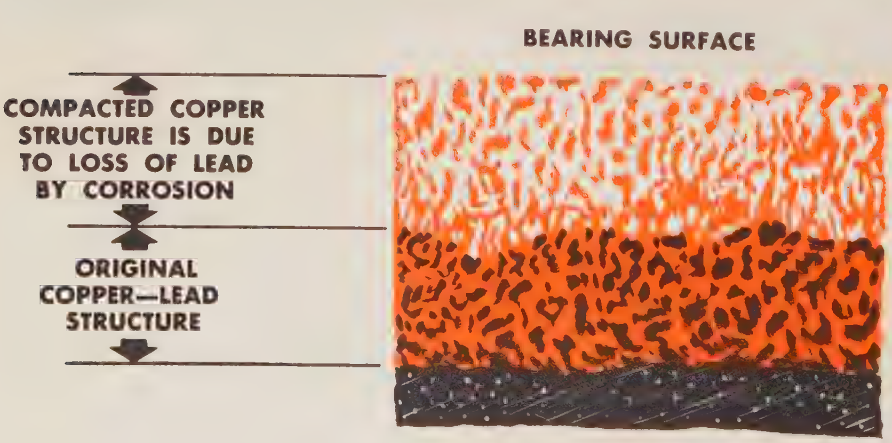
BEARING SURFACE
COMPACTED COPPER STRUCTURE IS DUE TO LOSS OF LEAD BY CORROSION
ORIGINAL COPPER—LEAD STRUCTURE

Fig. 4—Corrosive action due to lubricating oils.

	COMPOSITION IN PERCENTAGE					
	SAE 10	SAE 11	SAE 12	SAE 13	SAE 14	SAE 15
	90.0	86.0	88.25	4.5-5.5	9.25-10.75	0.9-1.25
ony	4.0-5.0	6.0-7.5	7.0-8.5	9.25-10.75	14.0-16.0	14.50-15.50
	0.35	0.35	0.35	86.0	76.0	remainder
er	4.0-5.0	5.0-6.5	2.25-3.75	0.50	0.50	0.60
	0.08	0.08	0.08			
ic	0.10	0.10	0.10	0.60	0.60	0.80-1.10
th	0.08	0.08	0.08			
and Aluminum	none	none	none	none	none	none

le VI—S.A.E. standard babbitt metals. The babbitts should be given careful consideration due to ir low cost and ease of handling.

	COMPOSITION IN PERCENTAGE	
	SAE 48	SAE 480
Copper	67.0-74.0	60.0-70.0
Lead	25.0-32.0	30.0-40.0
Silver	1.5	
Zinc	0.1	
Phosphorus	0.025	
Iron	0.35	0.35
Tin		0.05
Other elements	0.15	0.3

Table VII—Specifications for S.A.E. standard copper-lead bearing alloys. These alloys are used where the load-carrying ability must be greater than that of the babbitts.

Common bearing materials are classiied as to their resistance to corrosion in Table IV. This table should be used with iscretion since the intermediate and orrodible alloys may reverse their acivity in the presence of certain lubricants. Bearing corrosion has now been greatly diminished due to detergents and inhibtors which presently are being added to ubricating oils.

ost

The selection of the proper bearing etal may, more often than not, be nfluenced by cost. There are, no doubt, nstances where the cost of a single earing may be small as compared to the otal cost of the machine. This is not an ngineering justification, however, for eliberately using silver if a simple bronze ushing would be satisfactory. The aproximate order of increasing cost of earing metals is shown in Table V.

Commercial Bearing Metals

The properties which a bearing metal ust have if it is to perform its function roperly can be divided into three main lasses:

- Proper structure
- Satisfactorily balanced mechanical properties
- Easy melting, casting, and bonding properties.

A bearing metal has proper structure if it has a soft matrix with sufficient plasticity to conform to slight irregularities in the machining and alignment of the shaft and to allow any abrasive particles in the lubricant to become embedded in the bearing metal.

If a bearing metal has balanced mechanical properties it resists the shock of impact loads, has sufficient strength, ductility, and resistance to compression, and does not crack or squeeze out under heavy loads in applications involving high temperatures.

Easy melting, casting, and, most important, good bonding properties are especially desired in a bearing metal. The metal must adhere firmly to the steel piece used as a backing and should not chip off or separate from the backing during operation.

The Babbitt Metals

In choosing a metal to be used as a bearing, the tin-base and lead-base alloys (babbitts) should be given careful consideration because of their ease of handling and low cost. It is necessary with either the tin-base or lead-base alloys to have a minimum lining thickness properly bonded to a steel back, consistent with the conformability and embedability requirements of the application, in order to secure maximum load-carrying ability and fatigue life at elevated temperatures. Lead-base bearings have the advantage of lowest cost but their ability to support high loads with *low oil temperatures* is less than the tin-base babbitts when *thick linings* are used. When the thickness is less than about 0.005 in., however, no appreciable difference is to be found in load-carrying ability at high temperatures of the numerous types of lead-base compositions.

Babbitt linings of 0.003-in. to 0.008-in. thickness are common in commercial automotive engines, with 0.002 in. the low limit. Large stationary engines use thicknesses from 0.020 in. to 0.060 in. Table VI shows the S.A.E. standard babbitt metals.

Table VIII—S.A.E. standard brass and bronze bearing alloys comprise a wide range of various compositions and are valuable because of their low cost and resistance to wear when used with hard shafts or journals.

	COMPOSITION IN PERCENTAGE								
	SAE 40 Cast Lining	SAE 62 Cast Lining	SAE 64 Cast Lining	SAE 68A Cast Lining	SAE 791 Rolled or Wrought	SAE 792 Cast Lining	SAE 793 Cast Lining	SAE 794 Cast Lining	SAE 795 Rolled or Wrought
Copper	84.0-86.0	86.0-89.0	78.0-82.0	86.0-89.0	remainder	remainder	83.0 min.	68.5-75.5	88.0-92.0
Tin	4.0-6.0	9.0-11.0	9.0-11.0	0.50	3.5-4.5	9.0-11.0	3.5-4.5	3.0-4.0	0.25-0.75
Lead	4.0-6.0	0.30	8.0-11.0		3.5-4.5	9.0-11.0	7.0-9.0	21.0-25.0	
Zinc	4.0-6.0	1.0-3.0	0.75		1.5-4.0	0.5	4.0	3.0	remainder
Antimony			0.50			0.5			
Nickel	1.0	1.0	0.50			0.5			
Iron	0.30	0.15	0.15	2.5-4.0	0.1	0.35	0.35	0.35	0.1
Aluminum	0.005	0.005	0.005	8.5-9.5					
Phosphorus			0.25						
Silicon	0.005		0.005						
Other elements					0.2	0.4	0.3	0.4	0.2

	COMPOSITION IN PERCENTAGE		
	XB-80S	750	GM-3889M
Aluminum	balance	balance	balance
Tin	6.5	6.5	0
Nickel	1	0.5	0
Copper	1	1	0
Silicon	0	2.5	4
Cadmium	0	0	1.0

Table IX—Compositions of three aluminum bearing materials.

	COMPOSITION IN PERCENTAGE	
	SAE 18	SAE 180
Cadmium, minimum	98.4	98.25
Nickel	1.0-1.6	0
Silver	0.01	0.5-1.0
Copper	0.20	0.4-0.75
Tin	0.02	0.01
Lead	0.05	0.02
Zinc	0.05-0.15	0.02

Table X—S.A.E. standard cadmium bearing alloys are used in specia designs where their additive cost is justified by the increase in fatigue life

Copper-lead Alloys

Copper-lead bearings are backed by steel to give strength and rigidity. They are widely used where loads are higher than can be carried by the babbitts, and are made by casting or by the sintering process using powdered metals. Table VII shows the S.A.E. specification of copper-lead bearing alloys. The higher lead-content alloy gives a higher anti-score characteristic, but at the expense of strength, and it is inferior in compression properties to the other copper-rich alloys. In general, however, the high lead-content alloys are superior to the white metals in load-carrying ability and their properties are not so much affected by operating temperatures. They are also more resistant to repeated flexure, which is important with present-day engine speeds.

To obtain higher strength, tin up to 3 per cent and silver up to 5 per cent are added at a sacrifice of anti-score quality. The tendency of such an alloy to score can be offset by overplating with a thin coating of lead alloy which results in one of the highest load-carrying plain bearings now in modern use. These are commonly known as tri-metal materials (Fig. 5).

Bronzes

Bronzes are valuable because of their low cost and wide range of characteristics, as determined by the many various compositions. They are especially resistant to wear when used with hard shafts or journals.

The number of commercial bronzes is very large. The S.A.E. specifications in Table VIII can be used as a guide in conjunction with Table I, which gives suggested applications for their use.

Aluminum Alloys

Aluminum as a bearing material is not new, but the metal's high coefficient of thermal expansion and bonding characteristics heretofore have been severe drawbacks. Recent research has led to the development of aluminum-alloy bearings having promising potentialities and desirable qualities.

Compositions of three aluminum bearing materials are shown in Table IX. The alloy XB-80S is a strip alloy and includes a steel backing, whereas alloy 750 is furnished without steel backing. GM-3889M material was developed by General Motors Research Laboratories Division and is used in the Moraine-400 bearing, manufactured by the Moraine Products Division. This material is produced by the strip process and is bonded to a steel backing (Fig. 6). The finished bearing carries a lead-tin-copper overlay not exceeding 0.001 in. in thickness and possesses excellent ductility and score-resistant properties. This lead-base electro-deposit includes sufficient tin to prevent corrosion. The addition of copper to the composition gives the overplate alloy strength and load-carrying ability, which enables the bearing to operate satisfactorily and withstand the fatiguing stresses imposed by the heavily loaded modern engines.

The Moraine-400 bearing is another tri-metal material which may be classified in the moderate-cost, high-load, high-speed group, and offers from six to ten times the bearing life of the conventional babbitt bearing material.

Cadmium Alloys

The cadmium alloys are used in very special designs where their additive cost is justified by the increase in fatigue life. Table X gives the S.A.E. specifications which are essentially the same as may be obtained commercially. The cadmium alloys are attacked by corrosive oils unless treated with indium.

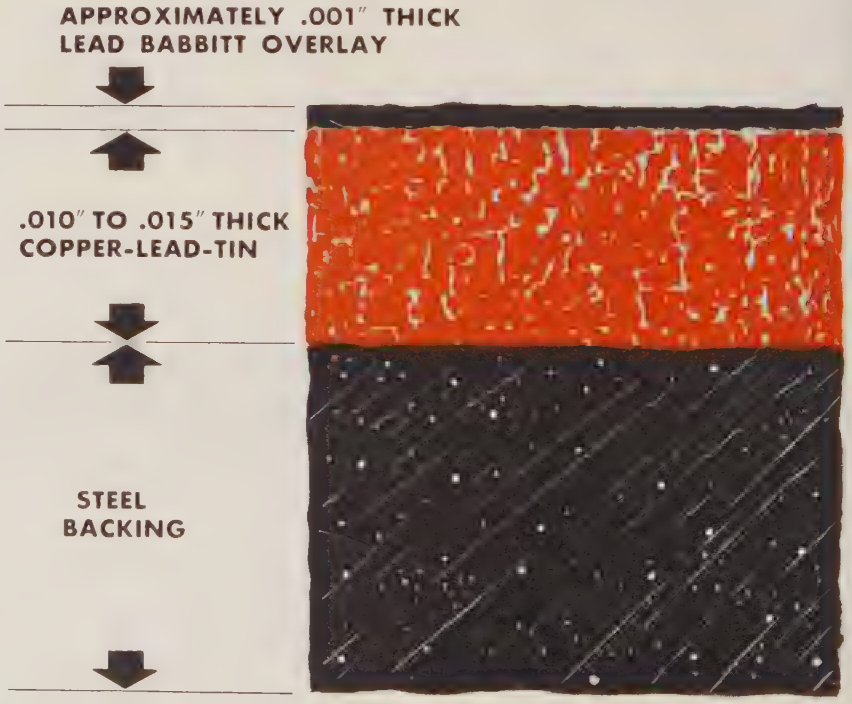

Fig. 5—High load-carrying ability is obtained with the use of a tri-metal bearing material. The copper-lead-tin section gives high strength. The use of a thin overlay of lead gives the bearing a good score-resistance characteristic.

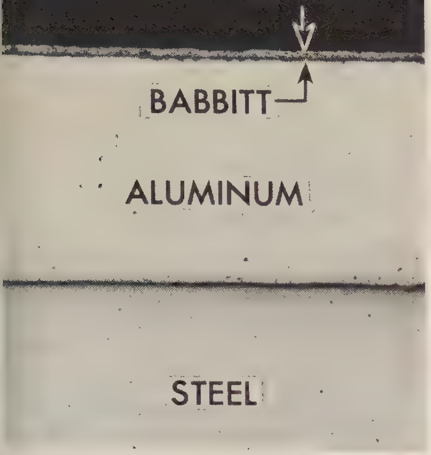

Fig. 6—Cross-sectional view of the Moraine-400 aluminum-alloy bearing, enlarged one-hundred times. The lead-babbitt overlay does not exceed 0.001 in. in thickness. The aluminum alloy is 0.010 in. to 0.015 in. thick. The bearing material was developed in the General Motors Research Laboratories as GM-3889M and is now used by Moraine Products Division.

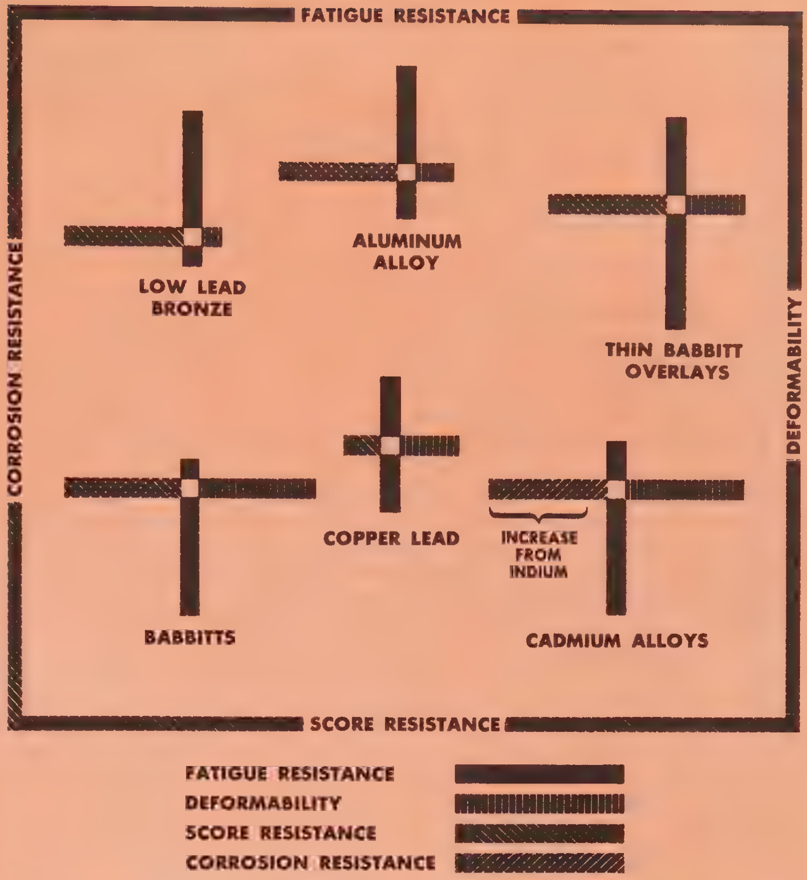

Fig. 7—Functional chart showing the four most important bearing-metal requirements. The length of each line may be taken as a measure of approximate order.

Miscellaneous Alloys

Two special types of bearing materials that are important commercially, but restricted to specific applications, are zinc castings and the porous type of sintered, powdered metal.

Zinc castings are used where low cost is desired and where speeds and loads are low. Zinc and its alloys are not good anti-friction metals and will score readily when speeds and loads become too high.

Sintered, powdered metal bearings are known as the oilless or self-lubricating bearings. The most common oilless bearing is made by compacting 87.5 to 90.5 per cent copper powder, about 9 per cent tin powder, and about 1.5 per cent graphite. The bearings are made with a controlled number of voids so that, when installed, they contain 15 to 35 per cent impregnated oil. They are, therefore, both bearing and lubricant and, if properly made, function for life in specific applications.

Conclusion

The determination of the metal to be used for bearing applications is not a simple one. A complete knowledge of the actual conditions under which an oil-film bearing is to operate is essential in order that a decision can be made as to the requirements the bearing must meet. With the operating requirements known, the selection of a bearing metal can then be made, which usually involves a compromise of all the various factors which have been discussed.

The functional chart (Fig. 7) shows the four most important bearing-metal requirements. Because it is very difficult to assign exact values to these properties, the length of each line may be taken as a measure of approximate order. The selection of the proper bearing metal for any application usually evolves itself into an art in which competent experience plays an important part. When new problems and conditions arise, it may be necessary for even the most experienced person to obtain new data.

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How Mathematical Reasoning Leads Way to Design of Round Gimbals To Predictable Stiffness

By GEORGE A. CAMPBELL,
EDWIN F. KATZ, and
ARNOLD B. RANINEN
AC Spark Plug Division

A new equation predicts within ± 12 per cent the frequency characteristic

Often, it is desirable to develop equations which will predict a particular characteristic of a given design before it is built. Such mathematical reasoning is an inherent part of the analytical approach to a design problem. This approach implies that the entire mechanism desired is foreseen on the drawing board with the precise knowledge that the mechanism—if built—will perform satisfactorily all of its intended functions. A case example of the development of such an equation is one which predicts the frequency characteristics of a round-membered gimbal system. Such a gimbal system conventionally is used to support a stable platform. A device such as a camera or a gyroscope could be mounted on this platform and isolated from vehicle motions. The equation here developed is not a design equation, as such, but may be used to predict the frequency characteristics of a system before it is built. This equation has been tested by AC Spark Plug Division engineers at Milwaukee and provides data within ± 12 per cent of the measured vibration of completed systems.

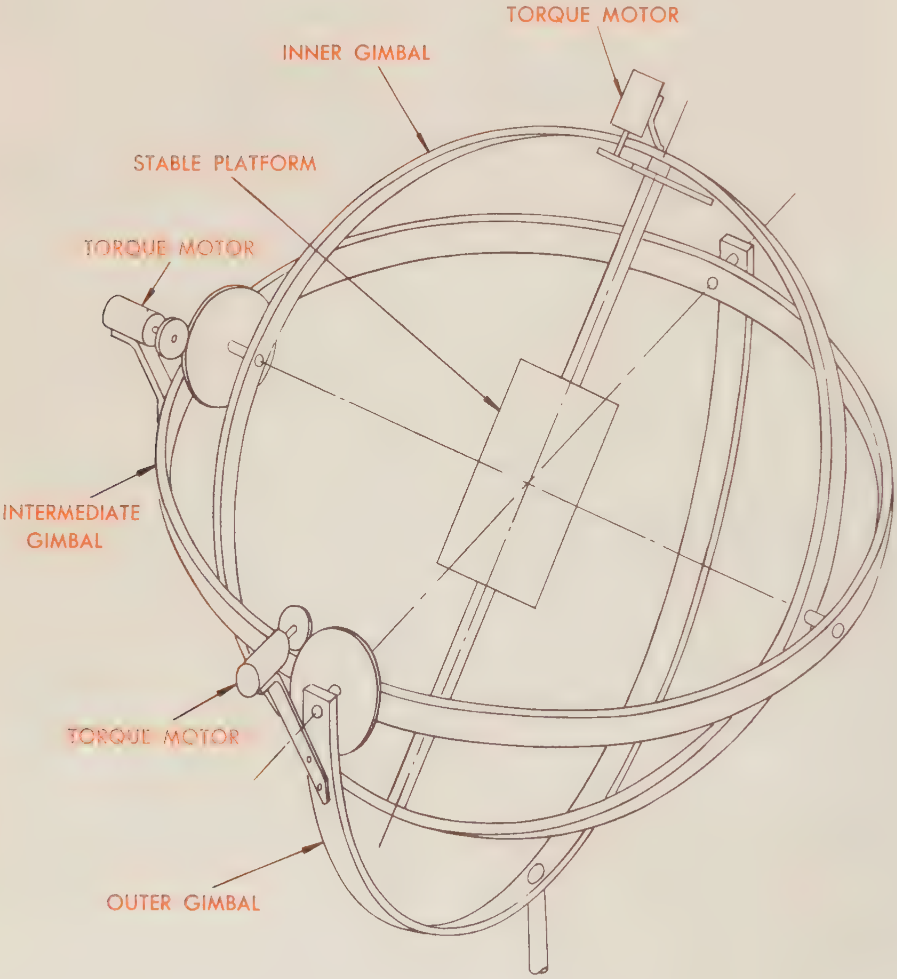

Fig. 1—Typical gimbal assembly.

A STABLE platform is often required in a vehicle for the support of equipment, such as cameras or gyroscopes, which must be isolated from vehicle motion. A system of gimbals, as shown in Fig. 1, is a convenient means of attaining this feature. Here, the reference platform, or stable platform, is housed in a system of gimbals—an inner, intermediate, and outer gimbal. The entire assembly is fixed to a vehicle, for example, a ship or aircraft. Torque motors are a part of a servomechanism system which maintains the platform in a stable position regardless of the rolling, pitching, or yawing action of the vehicle—which may be termed the carrier.

The design criterion for the structural members in any servo system is the resonant frequency of the servo loop. The resonant frequency of these members must be from six to ten times the resonant frequency of the servo loop in order to avoid oscillations of the system caused by a phase shift in the dynamics of the system.

To determine the frequency characteristics of the entire gimbal system, it is necessary to analyze first the stiffness of the individual gimbals. An analysis then may be made of the entire system with the gimbals combined in a configuration which results in the lowest systemic resonance. (An inspection of Fig. 1 discloses the fact that the load inertia varies with the actual position of the inner gimbals.)

Analysis of an Individual Gimbal

As an approximation, the gimbal is considered circular in shape and symmetrical along the three principal axes. The beam is loaded as shown in Fig. 2

(normal to the plane of the ring, at the ends of a diameter 90° from the support axis) which also pictures the forces, moments, and end conditions of half the gimbal, chosen as typical from the principle of symmetry. The load P* is half the couple supplied by the inertia of the supported mass, and the torque M_1 is the resisting couple from the gimbal torque motor. M_2 and M_3 are moments about the centroid of the cross-sectional area at the ends of the beam, at **A** and **B**, respectively, and arise from the application of load P.

The following assumptions are made:

(a) The beam is built in at **A** and simply supported at **B** since the only point of torque application is **A**. It should be noted, too, that the slope of the centroidal axis is considered zero at **A** only, not at **B**.

(b) The deflections are considered small so that the circular shape of the gimbals is retained under load. Consequently, no moments or forces are expected in the plane of the gimbal.

(c) The cross section of the gimbal is uniform and small compared to the radius of curvature.

Any solution to the problem will evaluate R_1, R_2, M_2 and M_3, and calculate the deflection under the load P. The resonant frequency then may be regarded as:

$$f_r = \frac{1}{2\pi}\sqrt{\frac{g}{\Delta_p}}\,.$$

From the summation of vertical forces:

$$\Sigma F_z = P - R_1 - R_2 = 0$$

and the summation of moments:

$$\Sigma M_x = Pr - M_1 = 0$$

$$\Sigma M_y = R_2r - R_1r + M_2 - M_3 = 0\,.$$

To compute M_3:

Consideration of the elastic energy defines the relationship between the deflection of the beam and the strain energy thus[1]:

$$M'\theta = \int_L \frac{M_p\,M_q\,ds}{EI_x} + \int_L \frac{T_p\,T_q\,ds}{GI_z}\,. \quad (1)$$

The auxiliary moments and torques are expressed as:

$$\left.\begin{aligned} T_p &= -M'\cos\phi \\ M_p &= M'\sin\phi \end{aligned}\right\} \quad (2)$$

and the actual moments and torques are:

$$\left.\begin{aligned} T_q &= R_2r\,(1+\cos\phi) - Pr\,(1-\sin\phi) - M_3\cos\phi \\ M_q &= Pr\cos\phi - R_2r\sin\phi + M_3\sin\phi\,. \end{aligned}\right\} \quad (3)$$

Substituting equations (2) and (3) into equation (1), integrating from $\phi = 0$ to $\phi = \pi$, and considering the load P acting from zero to $\pi/2$ only:

$$M'\theta = \int_L \frac{M'\sin\phi\,(Pr\cos\phi - R_2r\sin\phi + M_3\sin\phi)r\,d\phi}{EI_x} + \int_L \frac{-M'\cos\phi\,[R_2r(1+\cos\phi) - Pr(1-\sin\phi) - M_3\cos\phi]r\,d\phi}{GI_z}\,. \quad (4)$$

At point **B** the angular deflection in torsion is zero and $\theta = 0$; therefore, solving equation (4) and substituting limits

$$\frac{1}{2}\left(\frac{1}{EI_x} + \frac{1}{GI_z}\right)[Pr^2 - R_2r^2\pi + M_3r\pi] = 0$$

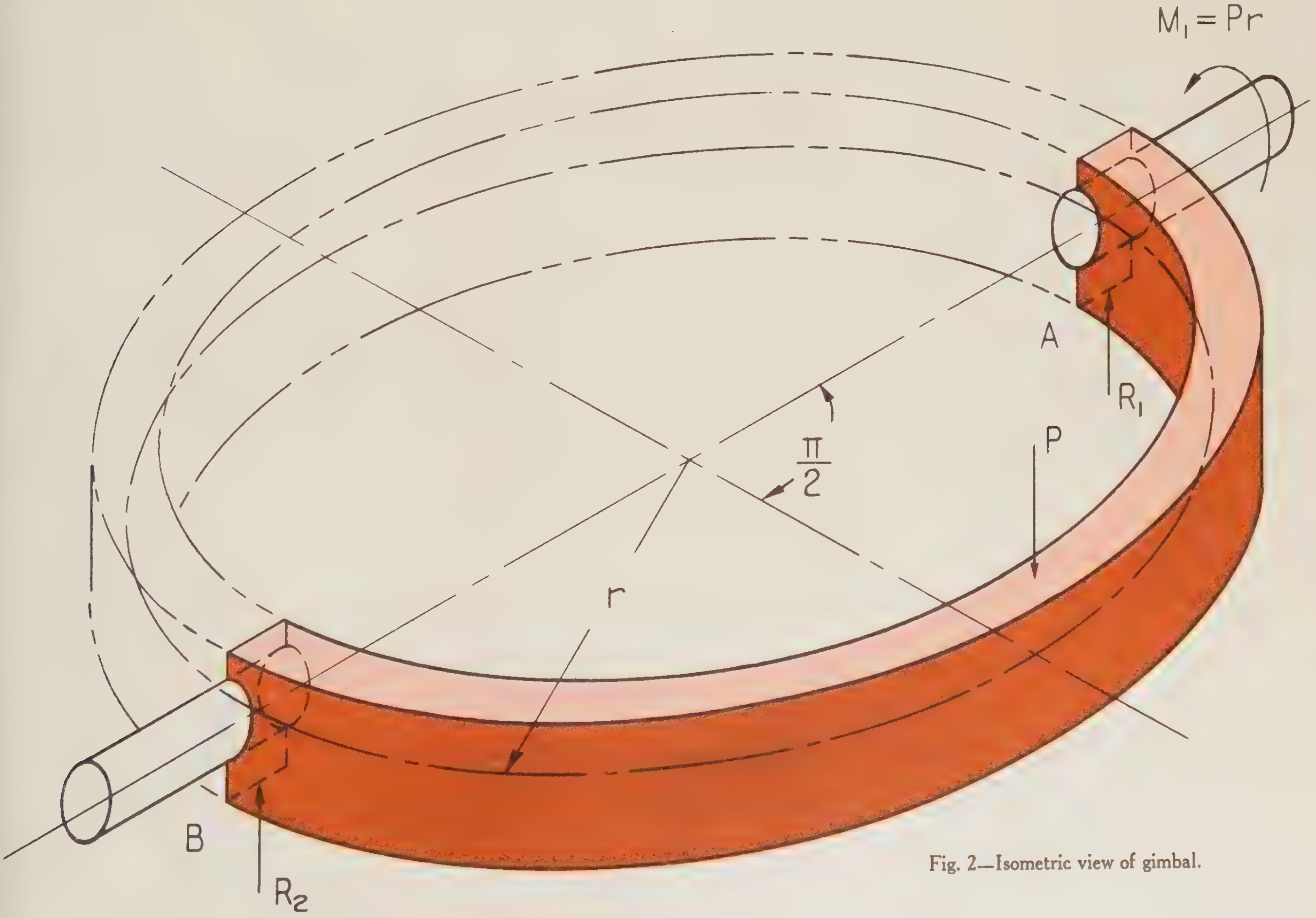

Fig. 2—Isometric view of gimbal.

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*Nomenclature on page 30.

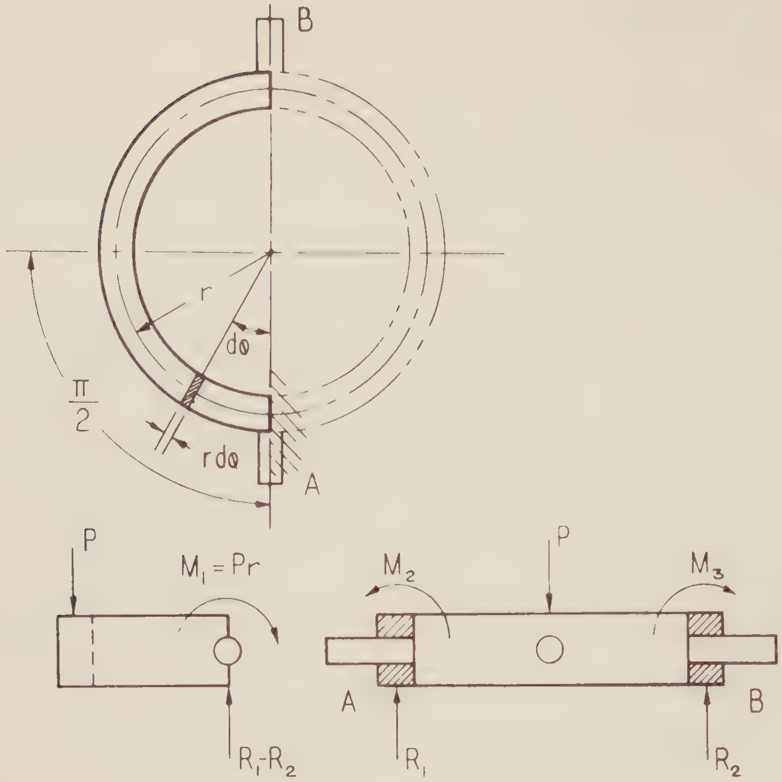

Fig. 3—Orthogonal views of circular gimbal.

but

$$\frac{1}{2}\left(\frac{1}{EI_x}+\frac{1}{GI_z}\right) \neq 0$$

therefore,

$$Pr^2 - R_2 r^2 \pi + M_3 r \pi = 0$$

and

$$M_3 = R_2 r - \frac{Pr}{\pi} \text{.} \qquad (5)$$

To compute R_2:

Again, applying auxiliary moments and torques and assuming the deflection normal to the plane of the gimbal at **B** equal to zero, equation (1) becomes:

$$P'\Delta_B = \int_L \frac{M_p\, M_q\, ds}{EI_x} + \int_L \frac{T_p\, T_q\, ds}{GI_z} \text{.} \qquad (6)$$

The auxiliary moments and torques then become:

$$\left.\begin{aligned} T_p &= P'r(1+\cos\phi) \\ M_p &= -\,P'r\sin\phi \text{.} \end{aligned}\right\} \qquad (7)$$

The actual moments and torques are the same as stated above in equation (3).

Substituting in equation (6), integrating from $\phi = 0$ to $\phi = \pi$ and setting limits, again recognizing that the effect of P extends from $\phi = 0$ to $\phi = \pi/2$, the expression for R_2 becomes:

$$R_2 = \frac{P(\pi-2)}{2\pi} \text{.} \qquad (8$$

Considering the beam configuratio shown in Fig. 3, the deflection under th load P may be calculated in the followin manner:

The auxiliary moments and torque are:

$$\left.\begin{aligned} M_p &= P'r\cos\phi \\ T_p &= -\,P'r(1-\sin\phi) \text{.} \end{aligned}\right\} \qquad (9$$

The actual load effects at any poin on the beam are:

$$\left.\begin{aligned} T_q &= R_2 r(1+\cos\phi) - Pr(1-\sin\phi) - M_3\cos\phi \\ M_q &= Pr\cos\phi - R_2 r\sin\phi + M_3\sin\phi \text{.} \end{aligned}\right\} \qquad (10$$

Evaluating the elastic energy in th beam:

$$P'\Delta_p = \int_L \frac{M_p\, M_q\, ds}{EI_x} + \int_L \frac{T_p\, T_q\, ds}{GI_z} \text{.} \qquad (11$$

After appropriate substitutions an operations, equation (11) reduces to

$$\Delta_p = \frac{Pr^3}{EI_x}\left(\frac{\pi}{4} - \frac{1}{2\pi}\right) + \frac{Pr^3}{GI_z}\left(\frac{\pi}{2} - 1 - \frac{3}{2\pi}\right) \text{.} \quad (12$$

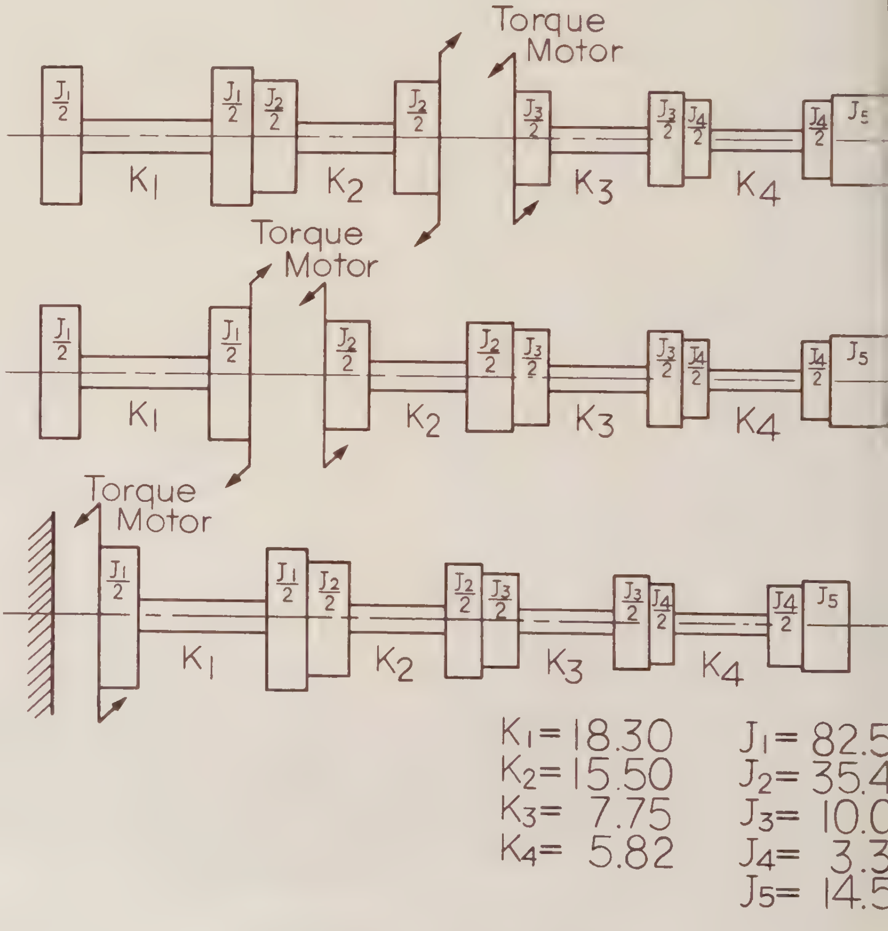

Fig. 4—Holzer analogy for gimbal assembly.

Station number	Moment of inertia, J lb-in. sec^2	J $\omega^2 \times 10^{-6}$	Angular displacement of disc, Θ radian	Inertia torque of disc, J $\omega^2\Theta \times 10^{-6}$	Torque summation = torque on shaft, $\Sigma J\,\omega^2\Theta \times 10^{-6}$	Shaft stiffness, K $\times 10^{-6}$ lb-in./radian	Angle of twist of shaft, $\frac{1}{K}\Sigma J\,\omega^2\Theta$
1.							
2.							

Table I—Tabular form for Holzer Solution.

Simplifying, the equation becomes

$$\Delta_p = 0.627\frac{Pr^3}{EI_x} + 0.093\frac{Pr^3}{GI_z} \qquad (13)$$

vhich is the relationship describing the lesign parameters for gimbal deflection.

As stated previously, the resonant freuency may be expressed:

$$f_r = \frac{1}{2\pi}\sqrt{\frac{g}{\Delta_p}} \cdot$$

A more general solution to the probem would be to consider the plan view f the beam as rectangular with rounded orners. The majority of gimbals deigned at AC Spark Plug Division are of his configuration. A complete treatment f the general solution has been develped by the authors but space limitaions prohibit including the results in his paper.

Analysis of Gimbal Assembly

It is possible to simulate the dynamics f a gimbal assembly by separating the nertia effects from the spring effects of ach gimbal and setting up the torsional ystem shown in Fig. 4. The inertia of he stable platform is known and the nertia of successive supporting gimbals s divided, half on each end of a massless, onnecting torsional spring. The wellnown Holzer method[2] can then be pplied by assuming an input angle of ne radian and calculating the frequency t which the input angle is independent f the torque applied. It is necessary to btain the solution for the outer three orque motors considering load—torque nd reaction-torque conditions. Table I nd Fig. 4 are typical of the calculations nd analogy associated with the Holzer olution. In practice, the elasticity of the lrive motors was not considered since he motors are located on normally orthgonal axes and cannot become colinear xcept under conditions of operation not rovided for in most systems.

A plot of external torque vs frequency (Fig. 5) represents the resonant frequency of the system shown in Fig. 4c. This system is based on the physical parameters of a preliminary gimbal assembly.

Experimental Work

The stiffness of each gimbal in two support systems was measured and the results agreed within ±12 per cent of the predicted values. These stiffnesses were measured by determining the load-deflection curve of each gimbal with the drive end of the supporting axis clamped. Table II compares the experimental and predicted stiffness values for four gimbals having a rectangular plan view.

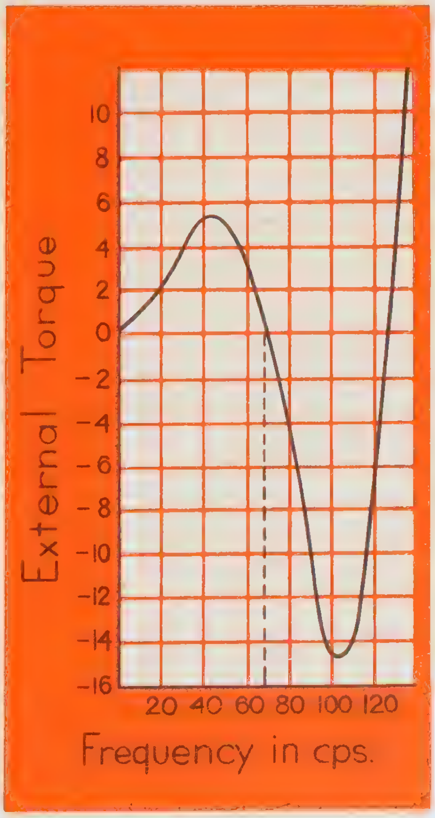

Fig. 5—External torque vs frequency for Holzer Solution.

Design Considerations

The relative efficiency of a box section with respect to an I-beam was determined with each beam having both equal wall thickness and depth-to-width ratio. The results are shown in Table III.

Computations were made on beams having a wall thickness of 3/8 in. and each beam's outside dimensions were 5 in. by 2 in. Of particular interest in Table III are I_z and the determination of its values for each type of beam. Here, I_z is regarded as an index of torsional stiffness and it arises from the application of the membrane analogy[3] for torsion in non-circular sections. It is used in the following manner:

$$\theta = \frac{M}{I_z G}$$

where

M = twisting moment
θ = angle of twist per unit length.

These values are directly applicable to the deflection formula derived herein and they define a trend toward the use of a box section instead of an I-beam.

Conventional theory[4] may be used in computing I_z. In the case of the box section, dimensions were labeled as shown in Fig. 6. The equation, substituting quantities from Fig. 6, is:

$$I_z = \frac{2t_1t_2(a - t_2)^2\,(b - t_1)^2}{at_2 + bt_1 - t_2^2 - t_1^2} \cdot$$

Conclusion

Deflection is a design consideration which lends itself aptly to a theoretical approach and the formulae derived for predicting stiffness of gimbal systems have proved particularly useful at AC Spark Plug Division. Work is underway now to optimize the depth-to-width ratio and wall-thickness ratio of the beam cross section to arrive at a gimbal package of minimum size and weight.

GIMBAL	TORSIONAL SPRING RATE (lb-in./radian)		RELATIVE ERROR (per cent)
	Computed	Experimental	
1	7.58	7.01	+8.1
2	4.38	4.49	−2.5
3	11.02	9.86	+11.8
4	2.58	2.67	−3.4

Table II—Experimental and predicted stiffness of gimbals.

Parameter	COMPUTED VALUES	
	Box section	I-beam
I_x	12.8 in.^{4}	10.9 in.^{4}
I_y	2.7 in.^{4}	0.5 in.^{4}
True Polar Moment	15.5 in.^{4}	11.4 in.^{4}
I_z	6.8 in.^{4}	0.15 in.^{4}

Table III—Effectiveness of a box section compared with an I-beam.

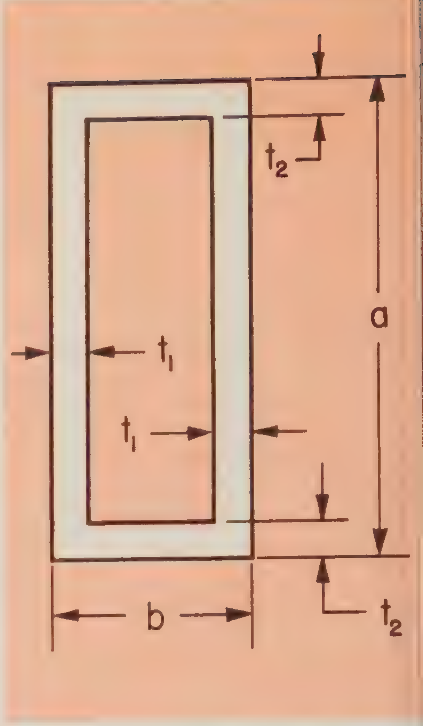

Fig. 6—Gimbal cross section.

Acknowledgment

Acknowledgment is made by the authors to groups and individuals in their organization who contributed materially to the study.

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Nomenclature

For the paper beginning on page 26: "How Mathematical Reasoning Leads Way to Design of Round Gimbals to Predictable Stiffness."

A = Cross-sectional area
Δ_B = Linear deflection at point B
Δ_p = Linear deflection under the load
E = Modulus of elasticity
f = Frequency
f_r = Resonant frequency
F = Force
g = Acceleration due to gravity
G = Modulus of elasticity in shear
I_x = Sectional moment of inertia about an axis in the centroidal plane
I_y = Sectional moment of inertia about an axis normal to I_x and I_z
I_z = Modified polar moment of inertia of the gimbal cross section according to the membrane analogy
J = Polar moment of inertia
M_1 = Applied torque from torque motor on rotational axis of gimbal
M_2, M_3 = Resisting moment to prevent torsional deflection of gimbal in plane of support
M_x = Moments about *x-x* axis
M_y = Moments about *y-y* axis
M' = Auxiliary moment
M_p = Bending moment at any section of beam due to an auxiliary load P' or moment M'
M_q = Bending moment in beam due to actual loading
P = Concentrated load
P' = Auxiliary load
R_1, R_2 = Reactions at ends of support axis
r = Radius
T_p = Torque at any section of beam due to an auxiliary load P' or moment M'
T_q = Torque at any section of beam due to actual loading
θ = Torsional deflection
ϕ = Angle

Designing Simplicity, Ease of Manufacture, and Safety into an Automotive Electrical System

By ERNEST A. LEAVENGOOD
and DONALD W. SEVERANCE
Oldsmobile Division

Taking the entanglement out of the wiring system of an automobile

he automobile owner might be amazed at the number of wires, cables, fuses, and her equipment necessary to operate all of the automotive accessories dependent upon ectricity for their operation. To him, the electrical system may represent just an ntanglement of wires and a problem when it comes to finding a blown-out fuse. In a ay, the same type of problem confronts the automotive manufacturer. The assembly, spection, and servicing of the electrical system represents time and labor that must e spent to wire correctly all the electrical components. If a method could be found to mplify the wiring of the automotive electrical system and still have it function properly, any problems could be solved that would benefit manufacturing—both from the assemy and economic viewpoints. Oldsmobile Division engineers set about to solve the probm and the result is a wiring and electrical system for the 1954 Oldsmobile that keynotes mplicity and introduces many new features.

THE increase in automotive accessories that depend upon electricity for their peration has reached a point where the ectrical system of the average automoile is now a maze of wires, cables, and ises. Problems are encountered in asembly, inspection, and service due to the ultitude of wiring connections that ust be made. Much time and labor is pent in the assembly and inspection hases of the assembly-line procedure nd in any servicing that the wiring or ectrical system might require after the ar has been in operation.

Oldsmobile Division's problem was pical in that the electrical system for e 1953 model had to have provisions r 56 separate leads and the 1954 model alled for a maximum of 82 leads. ecause this Division's cars are assembled ot only at its plant in Lansing, Michigan ut also at seven plants of the Buick-ldsmobile-Pontiac Assembly Division, e problem of assuring rapid and deendable assembly of the electrical system as particularly acute.

In planning the 1954 electrical system, udies were undertaken in February 953, not only to assure the high level of erformance gained with the introduction f the 12-volt electrical system in the en-current model, but also to make nprovements in the following areas:

- Simplification of the wiring system
- Improvement in the appearance of the wiring system
- Ease of assembly, inspection, and subsequent servicing when required
- Safety facilities included in the 1953 model.

In addition, it was desired to accomplish these changes without increasing cost.

When the design goals were established, Oldsmobile engineers made preliminary studies toward tentative solutions and then consulted engineers of supplier companies (which included the Packard Electric and Delco-Remy Divisions of General Motors) in finalizing their designs in time for the beginning of 1954 assembly.

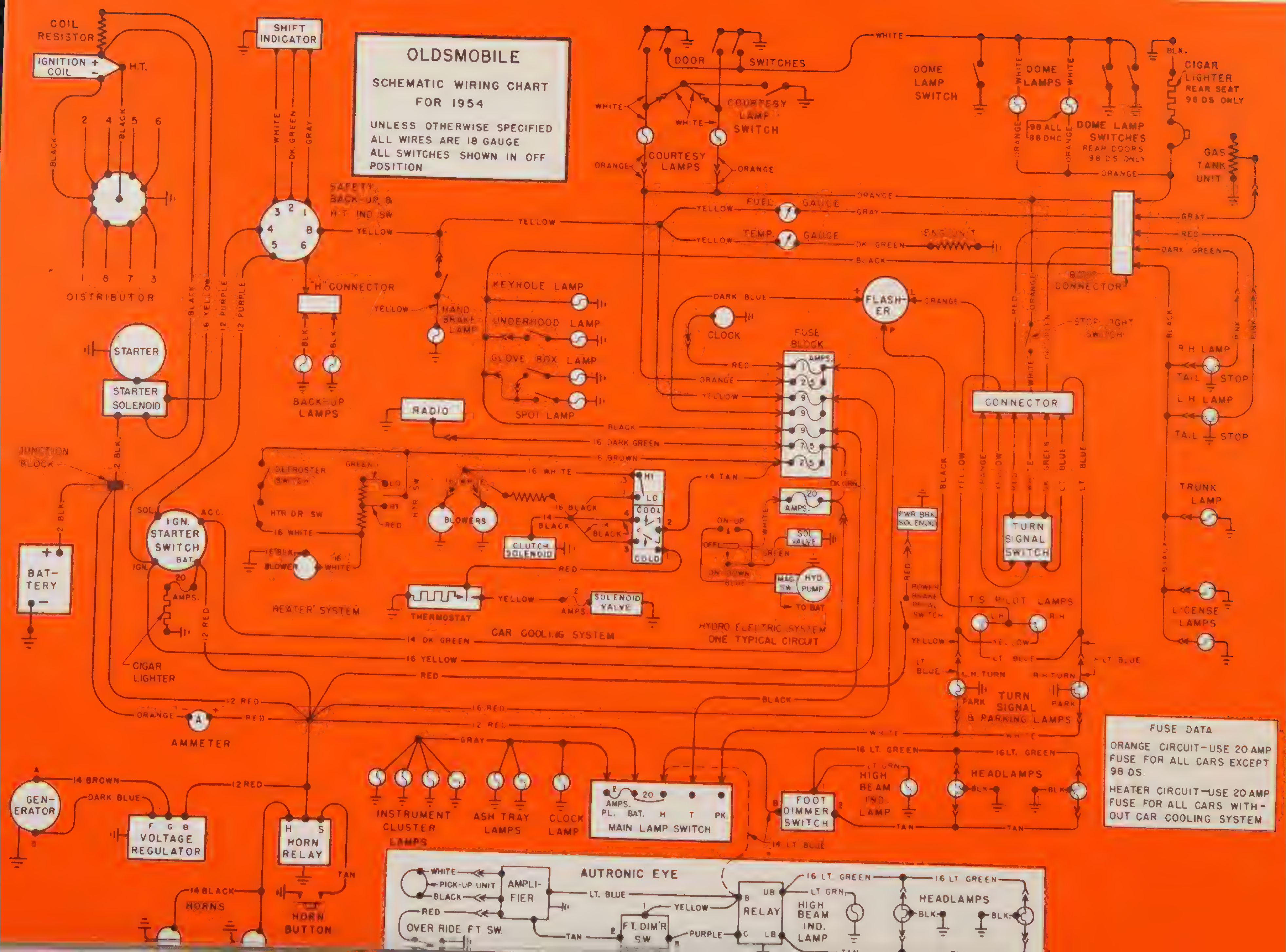
Wiring Simplification and Improvement in Appearance

The wiring of a complex electrical system can be made to appear quite simple when it is schematically drawn on paper, but translation from the wiring diagram to an actual installation is sometimes difficult. The Oldsmobile engineers faced the problem of not only taking the complicated electrical system and simplifying the wiring diagram on paper but also assuring that translating from the diagram to an installation would be just as simple as the wiring diagram appeared.

The first point that was considered in the re-designing of the wiring system was the wire itself. The engineering aim was to find some method by which it would be easy to identify each wire with its individual terminals. In arriving at a solution to the problem, the use of a numbering system as used for certain military aircraft was studied first. In this design the wires and corresponding terminals have the same number. After further study it was decided that a different system could be devised which would speed the assembly time more than could be accomplished by using a numbering system.

It was felt that the best way to simplify the assembly and inspection of the wiring system, and also improve its appearance, would be with the use of a *color code* to enable easy matching of wires and their terminal points. The wiring used in 1953 models, and common to automotive installations, was cotton covered with colored tracer markings. It was known from Service Department field reports that identification of the colored markings was difficult after the wire became smeared from exposure. It was decided that a new type of automotive wire, recently developed by the Packard Electric Division of General Motors, would overcome the difficulties. The insulation of this new wire consisted of vinyl plastic, available in a wide variety of colors. Tests showed that, after long periods of exposure to actual service conditions, the colors of the vinyl plastic still could be identified easily. This reason, plus the fact that the new wire possessed numerous other advantages over the braided type, led to its adoption on 1954 Oldsmobiles.

The use of a color code also has been extended to other component parts of the electrical system. Color dots are provided on the instrument cluster, ignition switch, fuse panel, light switch, and ignition resistor. This practice has reduced considerably assembly and service time as it is now a matter of merely connecting "the red wire to the red terminal." The inspection procedure likewise is simpli-



OLDSMOBILE

SCHEMATIC WIRING CHART
FOR 1954

UNLESS OTHERWISE SPECIFIED
ALL WIRES ARE 18 GAUGE
ALL SWITCHES SHOWN IN OFF
POSITION

FUSE DATA

ORANGE CIRCUIT–USE 20 AMP FUSE FOR ALL CARS EXCEPT 98 DS.

HEATER CIRCUIT–USE 20 AMP FUSE FOR ALL CARS WITHOUT CAR COOLING SYSTEM fied since colors of wire and terminals must match if the wiring operation has been done correctly. Fig. 1 shows the schematic wiring diagram of the 1954 Oldsmobile electrical system and the various color codes that are used.

Ease of Assembly, Inspection, and Service

The use of a color-coded wiring system aided in simplifying the assembly, inspection, and servicing of the wiring system, but engineering revision went still further in an effort to improve the overall electrical system. Considerable time was spent studying the 1953 electrical system in an effort to find ways in which the 1954 system could be improved.

A careful study of the 1953 wiring circuit led to a simplified circuit arrangement on the 1954 models. Now, most of the electrical-accessory wiring has been combined as an integral part of the main wiring harness. This reduces labor time on the assembly lines since separate installation and routing of the many accessory wires is no longer required. Because most of the accessory wiring is now an integral part of the main wiring harness, simplification in assembly and a neater appearance has been made possible. This can be seen in Fig. 2 which shows the 1954 Oldsmobile instrument-panel wiring arrangement, as viewed from the rear. Examination of the main wiring harness in Fig. 2 shows the ease with which assembly can be made. The wire leads from the harness are in an orderly arrangement and the color-coding of wires allows for ease in tracing in the wiring setup.

Engineering investigation also was directed to the wiring of the starter which, prior to 1954, had been difficult to work on because of its location beneath the engine. Proper inspection of the wiring after assembly also was difficult for the same reason. To improve this situation and solve the assembly and inspection difficulties, the 1954 model now uses a battery-cable junction block mounted on the left-hand filler plate. This design permits the complete wiring and inspection of the starter before it is installed on the engine.

The assembly phase of joining the car-body wiring to the chassis electrical system was given consideration. Investigation of this particular part of the electrical system led to a newly designed device which makes use of a multiple-contact disconnect plug. All wire leads in the car body now terminate at this plug and the body, as received from Fisher Body Division, the supplier, now is wired to the chassis electrical system by merely pushing the mating halves of the plug together, as shown in Fig. 3. The multiple-disconnect halves are keyed to prevent improper assembly.

In engineering the electrical system for ease in assembly, inspection, and service, changes also were made in the main light switch. Study of the previous design led to a completely redesigned light switch for 1954.

The main light-switch terminals on previous models created a problem in assembly by requiring the time-consuming method of placing from one to four wires under a single screw head. Because of the decreased current requirement of the 12-volt electrical system as used on Oldsmobiles, it was found that single *push-on* type terminals could be used effectively to replace the former method. The use of this type of terminal has simplified assembly and inspection of this item and decreased the time formerly required to perform these two operations. The redesigned light switch also reduces the number of switch terminals from nine to five and the number of wire leads from thirteen to five. Fig. 4 shows the simplicity and neat appearance achieved in the 1954 light switch as compared to the 1953 switch. The terminals are vividly marked with bright colors to match the attaching wire color.

Fig. 1—(Left) Schematic wiring diagram of the 1954 Oldsmobile electrical system showing the various color codes that are used.

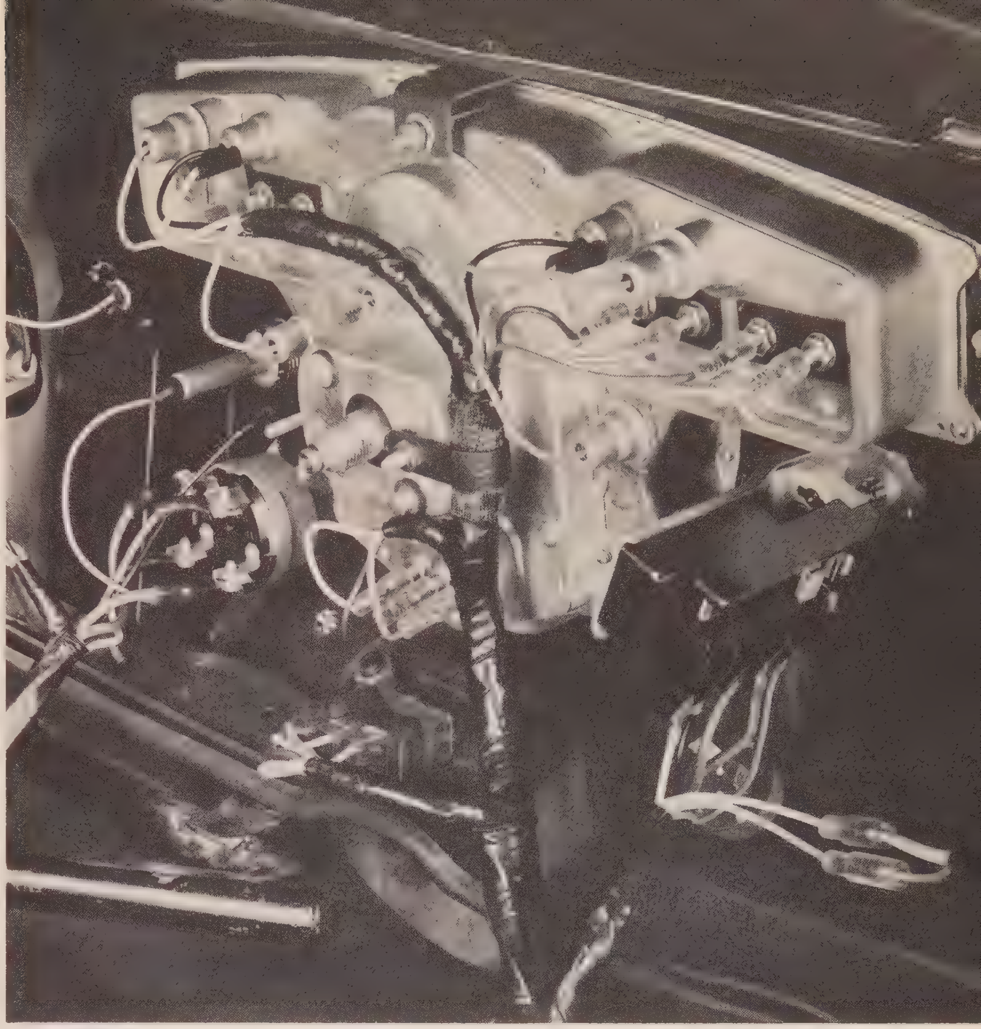


Fig. 2—Instrument-panel wiring on the 1954 Oldsmobile as viewed from the rear. Simplicity and improvement in appearance has been achieved through the use of a redesigned wiring and electrical system in which most of the electrical-accessory wiring has been combined as an integral part of the main wiring harness. The harness, which was designed by Oldsmobile engineers and is manufactured by Packard Electric Division, is tailored to provide ease in assembly. It can be seen that the exposed wires have a minimum distance between the harness and the connections.

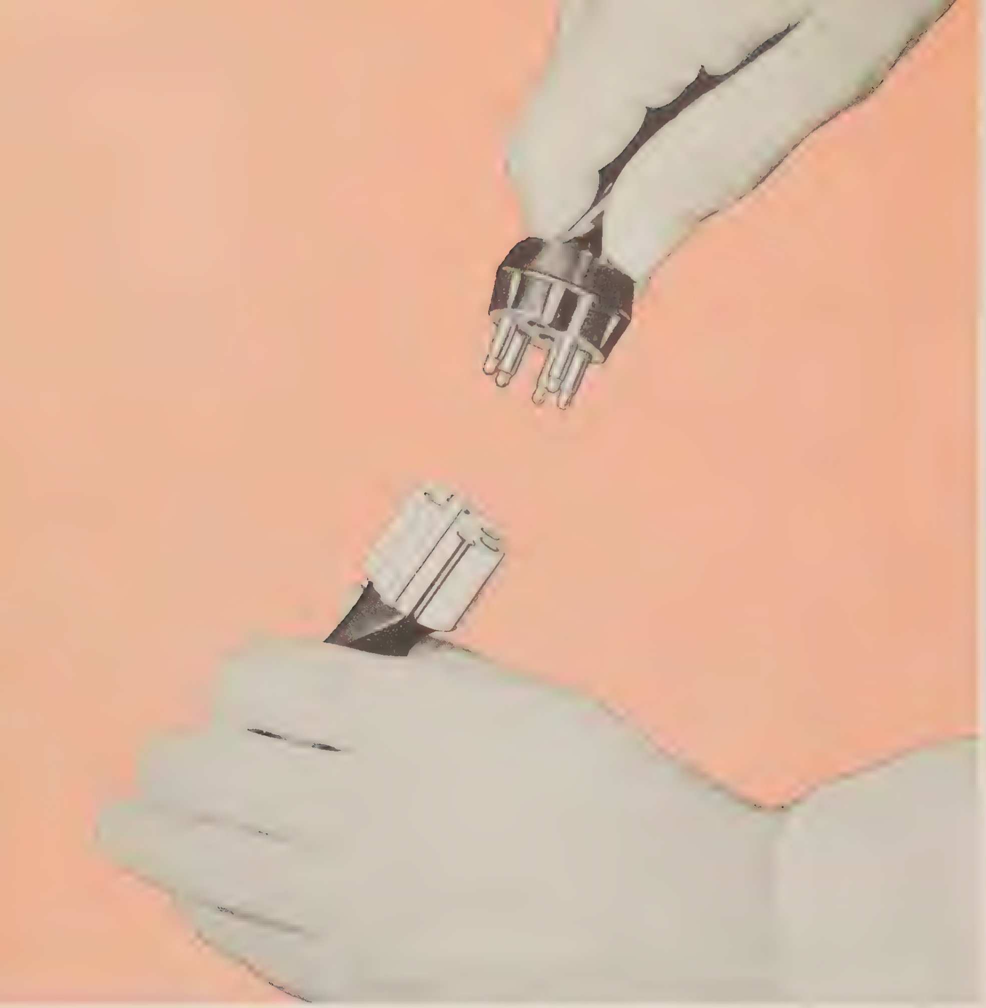


Fig. 3—Multiple-disconnect plug used for the first time on the 1954 Oldsmobile. Through the use of this plug it now is possible to wire the car body to the chassis electrical system by merely pushing the mating halves of the plug together.

The individual, in-line type fuse holder on previous models was an item that created problems in assembly, inspection, and service. The 1953 Oldsmobile, equipped with all of the electrical accessories available to the customer, had a total of 19 fuses in different locations. Many of the fuses were difficult to locate because they were obscured by the car wiring. The majority of the fuses were of the *in-line* type and difficult to take apart since it was necessary to use both hands in performing the operation behind the instrument panel. The subject was studied carefully in an effort to improve the condition. The result was a newly designed combination junction block and fuse panel, which is shown in Fig. 5. The new design centralizes the fuses and circuit junction points and also employs the use of push-on type connectors. In contrast to the number of fuses on previous models, the new design uses only seven fuses on the panel and one instrument-light fuse located on the light switch to protect the dimmer resistor. The fuse panel also has all circuits clearly labelled and a color-code system similar to that found on the light switch.

As mentioned previously, most of the electrical-accessory wiring has been combined as an integral part of the main wiring harness. Because of this, it is possible to combine a number of lamps into one circuit and protect them with a single fuse. In these cases a common wire color is used which matches the color on the fuse panel adjacent to the fuse which protects the circuit. For example, the glove-box lamp, under-hood lamp, keyhole lamp, spot lamp, tail lamps, trunk lamp, and license lamps are all wired with a black wire and all are protected with a common fuse which is color-coded black on the fuse panel. All of the above lamps are fed from a common feed wire from the tail-lamp terminal of the light switch. Since it is not possible to include names on the fuse panel of all items protected by a single fuse, the new color code enables the service man simply to observe the color of the wire at the point where service is required. The fuse which may require replacement is identified by a color dot on the panel to match the wire color.

Redesign Introduces New Safety Feature

The engineering investigation of the 1954 wiring and electrical system was not

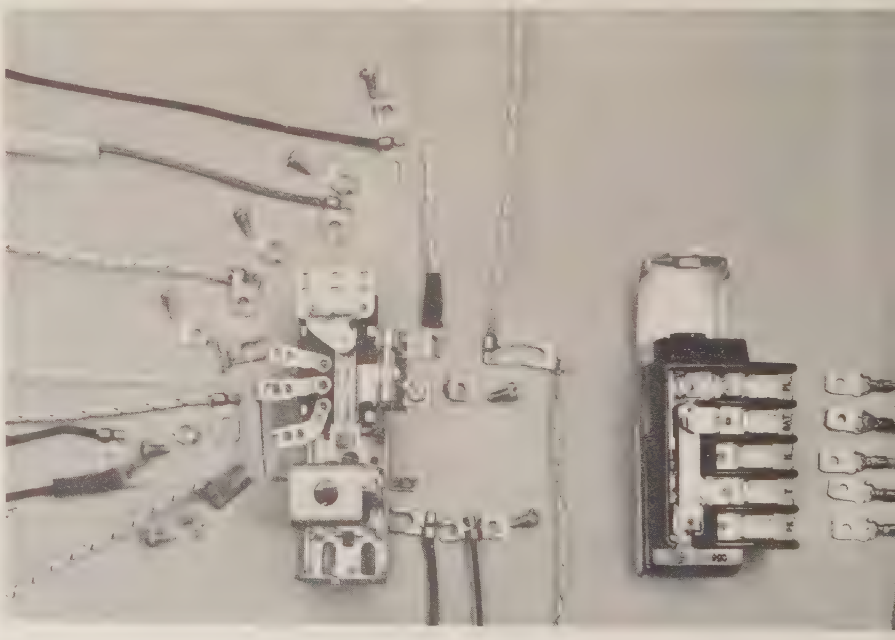


Fig. 4—Comparison between 1953 and 1954 light switches. Neat appearance of the 1954 switch (right) is made possible due to the number of switch terminals being reduced from nine to five and the number of wire leads from thirteen to five.

devoted wholly to designing electrical components that would simplify assembly, inspection, and service. The topic of safety also was considered and many new safety features have been incorporated into the new system.

The possibility of short circuits has been virtually eliminated by the newly designed main light switch. The switch terminals are recessed between molded bakelite barriers to prevent the possibility of short circuits to adjacent terminals. The bakelite barriers also provide protection from accidental shorts caused by misplaced bowden cables and wire clips. The combination junction block and fuse panel also has the molded bakelite-barrier provision which serves a twofold purpose. The barrier affords the same protection against possible short circuits as in the main light switch, and also eliminates the necessity for a protecting panel cover which, in turn, allows for easy inspection and service of the fuses.

As an added safety precaution which is included in the 1954 wiring and electrical system, all body wiring—with the exception of the seat-adjusting motors and convertible-top actuating motors—now is fused. This insures maximum protection from possible fires that might result from partially or intermittently shorted strands of an electric cable.

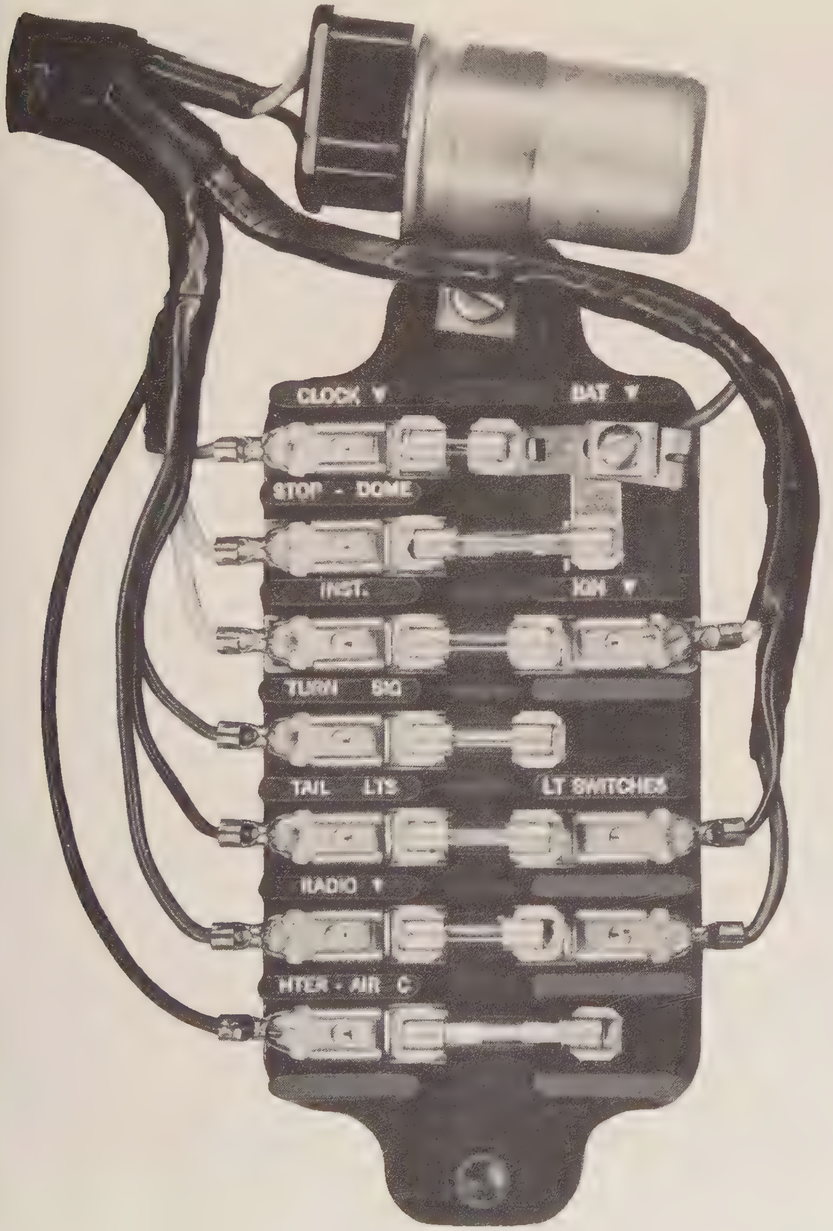


Fig. 5—Combination junction block and fuse panel used on the 1954 Oldsmobile. *Push-on* type terminals are now used and possible short circuits between adjacent terminals have been eliminated with the use of molded bakelite barriers.

Conclusion

The overall results of the engineering revision of the wiring and electrical system of the 1954 Oldsmobile have proved beneficial. All of the new features have led to simplification in assembly, inspection, and service. Safety, as it involves the electrical system, has been improved with the new design of the electrical-system components.

In general, screw-type connections have been reduced to a minimum throughout the entire electrical system in favor of push-on types, thereby reducing assembly time and eliminating the human factor of loose connections caused by failure to tighten screws properly. The time required for service work has been reduced also as a result of the new system. The color dots which are provided on the various electrical components aid in indicating the correct wire colors which should be used when wiring these units.

A further benefit which has been derived from the new wiring and electrical system is the simplification which has resulted in the employe-training program. The training of new personnel to perform the 1954 wiring job is a simple matter as compared to 1953. After one trial, men have been able to wire instrument panels correctly without further reference to instructions or drawings.

Assembly, inspection, and service time have been reduced with the introduction of the color code. The redesigned light switch eliminates any possibility of miswiring and prevents short circuits. The use of a battery-cable junction block has simplified starter wiring. The newly designed combination junction block and fuse panel, with the push-on terminals, has decreased and centralized the number of fuses necessary.

As in the case of all engineering work, economic consideration must also enter the picture. Original estimates indicated that the time saved on the production line would more than offset the cost of the new wiring and electrical-system components. Early production experience on the 1954 Oldsmobile indicates that this estimate was correct.

The Physics of Automotive Radio-Interference Elimination

By BROOKS H. SHORT
Delco-Remy Division

Designing for better auto-radio reception through applied physics

Certain components of the automotive electrical system inherently tend to radiate energy at frequencies which adversely affect the radio reception of automotive radios and of nearby radio, television, and other receiving equipment. Reducing the effects of this radiation or eliminating the radiation through design are tasks of the automotive electrical engineer. The two basic approaches to the interference-suppression problem are filtering and shielding.

THE circuits used in automotive electrical equipment produce radio interference in copious quantity throughout the usable frequency range. This interference meant little to the automotive engineer in the past. When automobile radios began to be accepted by the public, however, it was found necessary to reduce interference so that reasonable broadcast receptions could be had.

During World War II, many engineers became acutely aware of the problems caused by interference. Some of the radio transmitters used by the armed services were of low power ratings. These instruments, as a result, transmitted weak signals with limited coverage. In many cases, any interference was too much if satisfactory communication was to be had.

Interference was a menace in another way. Large concentrations of vehicles with their combined interference levels made it possible for the enemy to locate tactical units and destroy them. At that time, Delco-Remy Division began to work very closely with the armed services in an effort to produce automotive electrical equipment with satisfactorily suppressed interference levels.

As a result of this preliminary work, the present civilian tasks are not too difficult. It is necessary that the automotive industry recognizes that there is a civilian problem. The advent of high-fidelity frequency-modulated transmissions presented a new source of entertainment that was susceptible to the undesired radiations from automobiles. In order for this service to be of maximum value, the undesirable automotive radiations had to be reduced. The civilian problem was complicated further when television became a reality, for here the interference not only detracted from the audible sound but also altered the television picture.

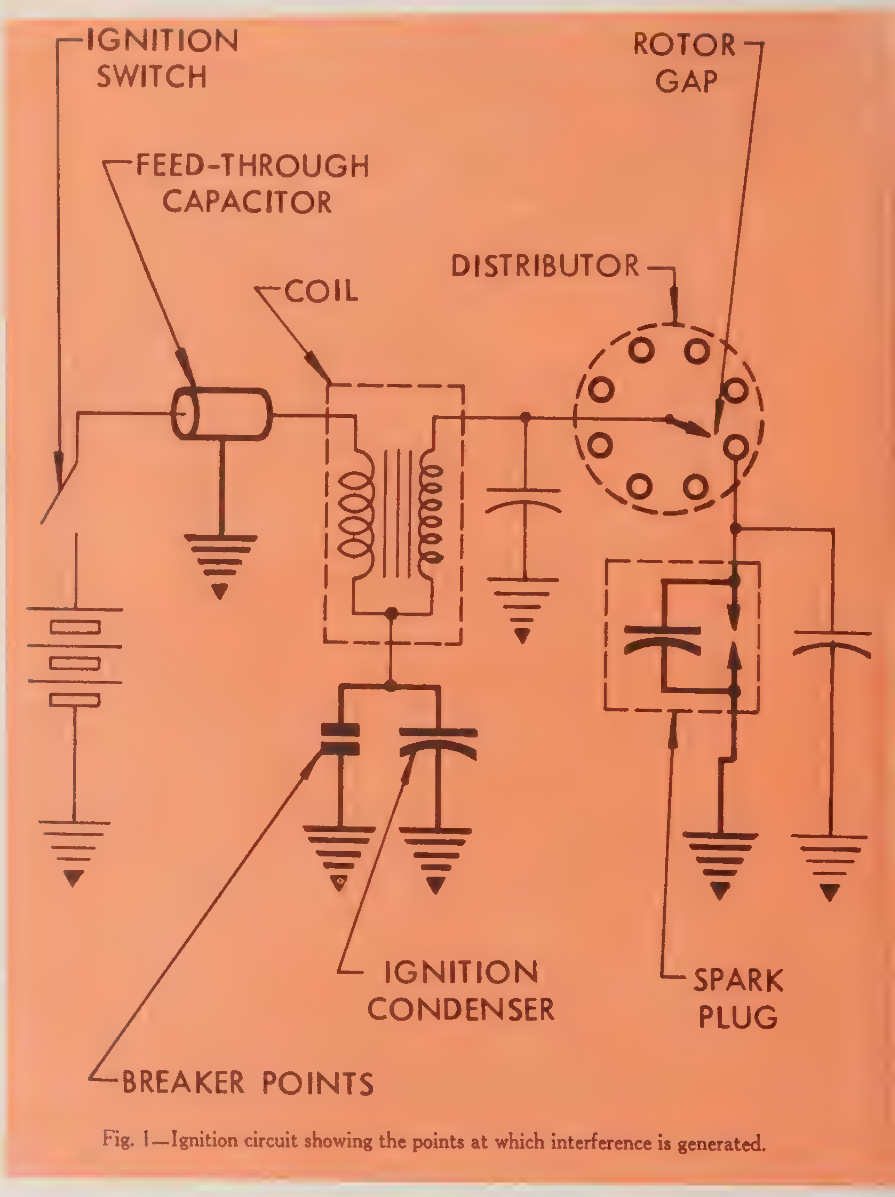


Fig. 1—Ignition circuit showing the points at which interference is generated.

The problem of elimination of automotive radio interference is a continual one, since each step toward a more efficient, better performing engine i accompanied by more serious radi interference.

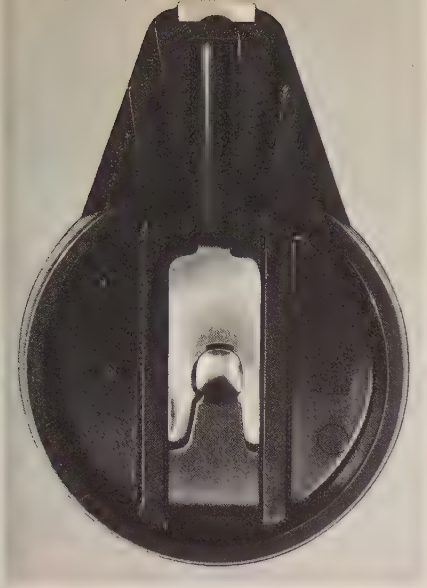


Fig. 2—Resistance rotor as installed on present-day passenger cars.

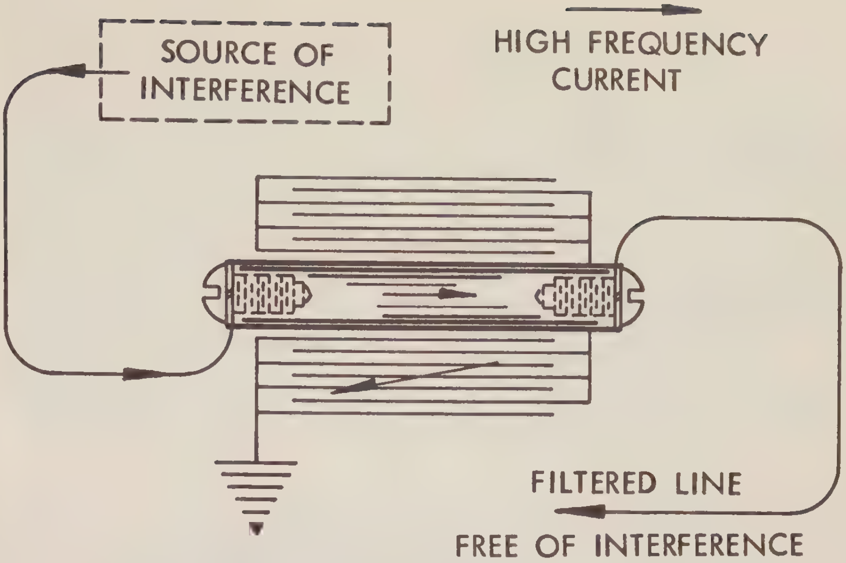


Fig. 3—Diagram of a coaxial or feed-through capacitor.

As yet, the automotive electrical engineers have not been able to develop devices that are capable of performing the functions of normal automotive electrical equipment without producing radio interference.

Ignition

There are three sources of radio interference in the ignition system (Fig. 1):

Ignition Condenser and Breaker Points

The first source of interference is associated with the ignition condenser, the breaker points, and the connections between them. During the time following the ignition pulse the contact points remain open. As a result, the ignition condenser becomes charged to the full battery voltage. In preparation for the next ignition transient, magnetic energy must be restored to the ignition coil. To do this the ignition points close approximately 30° before that ignition is required. When the points close, the energy which has been stored in the capacitor sends current through the breaker points. The combination of the condenser capacity and the inductance of the connecting devices results in a high Q circuit with a resonant frequency in the region of the present broadcast band. Luckily, the energy available in this circuit is low so that interference arising from this source is not too serious. Ignition engineers have found it possible to nest these offending components well down in the bowl of the distributor so that negligible interference is created from this source.

Rotor Gap

The second source of interference is found in the rotor gap. The electrical energy is fed from the ignition coil to the distributor rotor in the form of a wave of approximately 2,500 cycles per second. The potential of the rotor rises along that curve. At the exact moment the rotor gap breaks down, the voltage at the rotor drops instantaneously to near zero due to the sudden adding of the capacities that follow the distributor. Anything that can be done to slow down the rate of ionization in the rotor gap should reduce the noise.

A number of approaches have been tried. One method of attack includes a special rotor in which the sparking electrode is a thin disc of copper on the end of a carbon resistor. The resistor is allowed to extend beyond the plastic rotor casting. In this way, the capacity across the resistor has been minimized and it is necessary that all electrical energy that travels across the rotor gap be carried through the resistor. This approach materially reduces the ionization rate and greatly reduces the peak magnitudes of any undesirable radio-frequency transients. This approach is very effective for laboratory tests, but is of little practical value since the resistor is very fragile.

While the most perfect resistor rotor is too fragile for passenger-car application, the same principle can be incorporated in a rotor of a more practical nature with only a small loss in effectiveness. Many passenger cars are now equipped with resistor rotors of the type shown in Fig. 2.

Another approach that is used widely consists of the insertion of a 10,000-ohm suppressor resistor in the center tower and 5,000-ohm suppressor units in each of the output towers of the distributor. These resistors serve to limit the wave of current and they also tend to reduce the high-frequency currents that may flow as a result of the high-frequency voltages that appear at the time the gap breaks down.

Spark Plug

The third source of interference occurs at the spark plug and is of the same variety that appears at the rotor gap. This interference is the most serious of all in the ignition system for a number of reasons:

- The magnitude of interference is a function of the peak change.
- The frequency spectrum is determined by the rate of change.
- Spark-plug voltages usually are four to six times as great as the rotor breakdown voltages.

Only one side of the line can be treated in the spark plug since the plug screws into the head of the engine. The usual procedure is to have a 10,000-ohm suppressor resistor in series with the plug.

Suppression by Filtering

Some of the high-frequency energy that is generated at the time a spark

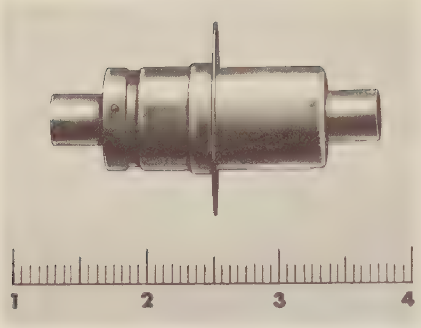


Fig. 4—A 2-microfarad, metalized-paper, feed-through capacitor.

plug breaks down travels back through the ignition wiring, through the distributor into the secondary of the coil, and is transferred through the coil to the primary winding. It is an unfortunate circumstance that practically every wire in the car is connected to this low-voltage ignition terminal. Since so many wires are connected to that point and their physical length varies so radically, a resonant length of wire can be found for every interference frequency set up in this system.

Because of this fact, it has been found desirable to insert a filter unit between the ignition coil and switch. This filter, of course, can take any number of forms, depending upon the degree of suppression required. Some engineers are inclined to lean toward pi-section filters. Others have found it possible to do an effective job by using a simple, low-inductance capacitor. For example, if one were to consider a 0.3-microfarad capacitor with a physical length from mounting bracket to terminal of 1 in., he would find the device to be resonant at 2.03 megacycles and to be of high impedance at 4 megacycles. In order for a capacitor to be effective for interference reduction, it must have extremely low impedance, or high attenuation, throughout the frequency spectrum involved.

During the war a number of engineers independently arrived at the design for such a low-impedance condenser. They wound their capacitors on a solid metal core. The undesirable transients were brought into the core and through it to one of the foil connections. The other foil connection was connected to ground (Fig. 3). In this way, the current flowing through the core set up a magnetic field 180° out-of-phase with the magnetic field set up by the current flowing in the condenser winding. The result was a capacitor having such a low distributed inductance that it retained capacitive action up to frequencies in the range of 1,000 megacycles. Such a by-pass unit is very effective throughout the frequency range.

The coaxial capacitor has been improved considerably by making the winding of metalized paper. This newer type of construction permits greatly increased capacity in the same physical size and in this way improves the attenuation and the frequency range covered by a given-size capacitor. A 2-microfarad capacitor of the metalized-paper variety is shown in Fig. 4.

Equipotential Surfaces

The methods of suppression described above, while effective in most cases, are inadequate in certain other applications. In cases where even a minute amount of interference must be considered as excessive, other steps must be taken.

One of these steps is very easy to describe but difficult to accomplish. This approach consists of enclosing all of the ignition components in a well-grounded equipotential surface. An equipotential surface may be achieved by completely enclosing the ignition coil and distributor in a metal-clad unit. This igniter then is connected by heavily shielded cables to

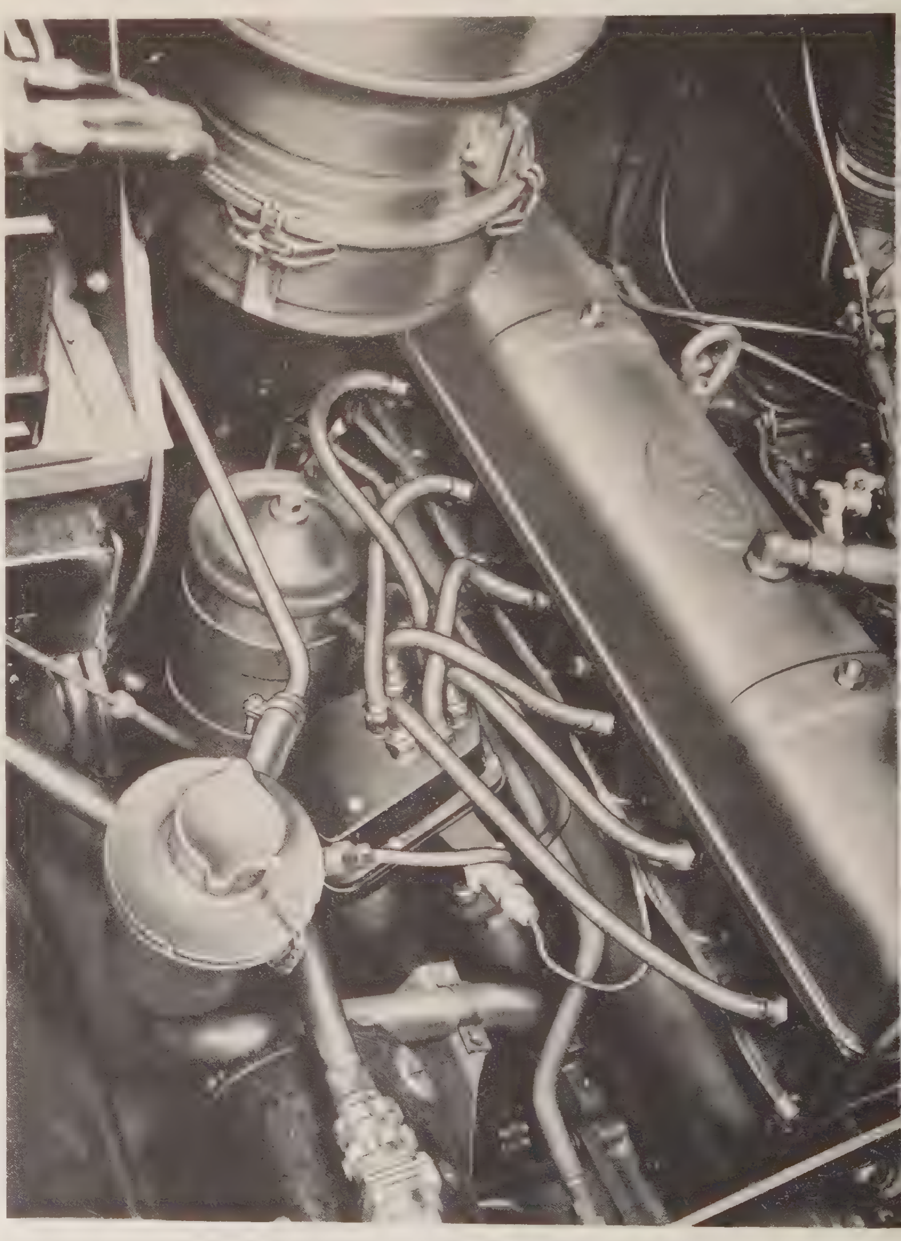


Fig. 5—The GMC Truck & Coach Division military engine showing the completely shielded ignition system.

shielded spark plugs. Such ignition systems currently are being supplied by General Motors to the armed services (Fig. 5). A somewhat less effective equipotential surface can be obtained on in-line, six-cylinder engines by mounting the distributor about midway on one side of the engine. The coil is mounted adjacent to the distributor. A cross-type shielding enclosure is bolted to the side of the engine in such a way that the shield and the engine completely enclose all parts of the ignition system.

Such a shielding enclosure has been used in the plastic-body automobiles. In the metallic-body cars the interference generated affected such services outside of the car as television and short-wave radio. The plastic-body car resulted in a new situation, for here the interference was to be found in excessive quantity in the installed automobile radio. The sheet-metal shield shown in Figs. 6 and 7 greatly reduced this interference in the installed radio and it also reduced the undesirable radiations in the television band.

In eliminating the last vestige of ignition interference, it is necessary to confine ground currents to certain prescribed paths. This action quite often is accomplished by using heavy, copper bond straps between various automotive parts.

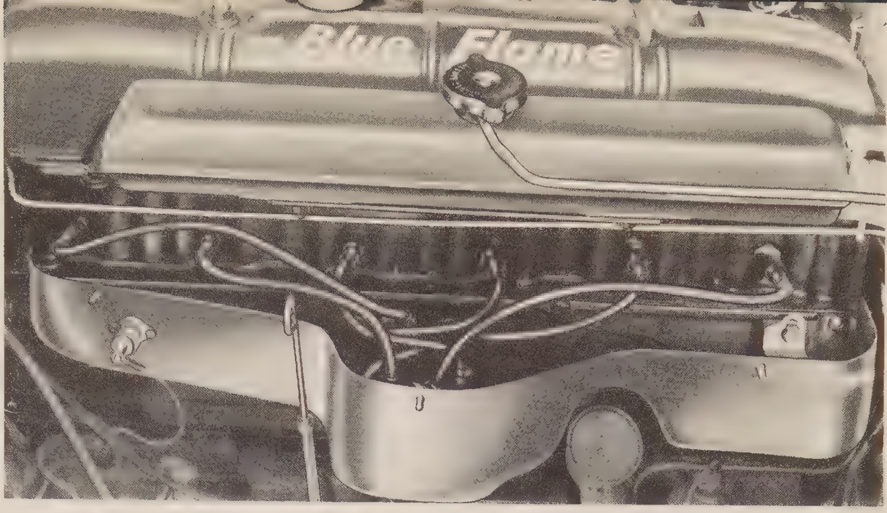


Fig. 6—The Chevrolet Corvette engine with the lower half of the *cross-type* shield in place.

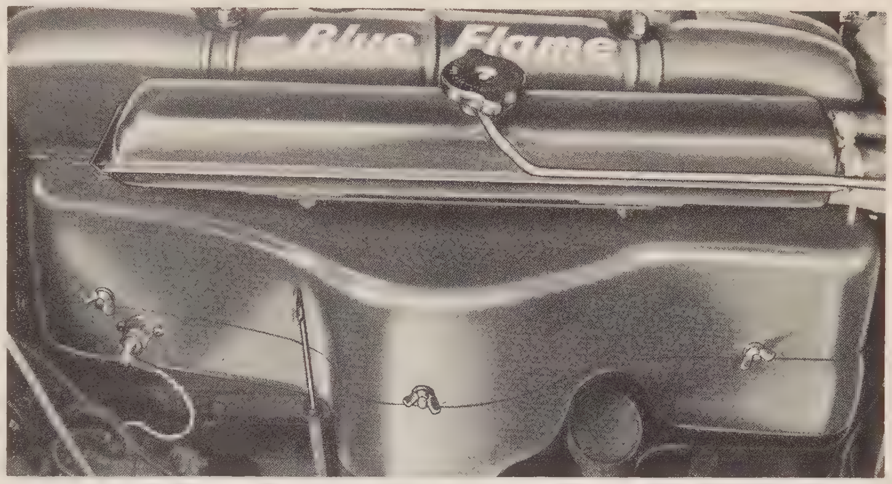


Fig. 7—The Chevrolet Corvette engine with the complete ignition shield in place.

Charging-Circuit Components

In the charging circuit the automotive electrical engineer is faced with a number of sources of radio interference.

The first source is the generator. Textbooks indicate that the current in any generator conductor is in one direction when that conductor is on one side of the armature. When the armature has rotated so that the conductor is on the other side, the current is reversed. Reversal takes place during the time the coil is connected to the brush.

A condition of ideal commutation is one in which current decreases uniformly with time until, at the halfway point, zero current flows through the coil. Following this event, current builds up as a linear function, but of reversed direction, until the coil leaves the brush, at which instant current of normal value and proper direction flows in the coil. Under this condition, no change in coil current needs to be made when the brush leaves the bar. Such commutation can be had in a machine designed for a particular output voltage having a specified output current and operating at a given speed.

The automobile generator, however, is required to operate over a wide range of speed, over a large range of voltage, and over a considerable range of output current. For that reason, it is practically impossible to design an automotive generator with perfect commutation. Any deviation from perfect commutation is accompanied by sudden electrical transients that are very effective producers of radio interference.

The second source of interference is present in the region of the commutator. A well-accepted theory has stated that all current carried between a brush and commutator bars is carried by a number of minute arcs. This fact partially explains the constant potential drop between the bar and the brush. When more current is carried, more arcs are formed in parallel but the voltage drop remains nearly constant. These arcs are continually forming and dying out and, each time an arc is formed, a number of radio-frequency vibrations are set up.

Luckily, both of the above interferences appear at low voltage and are easily suppressed by inserting a coaxial condenser in the armature circuit. This condenser must be located as close to the armature terminal as possible.

There is a third source of interference present in the generator that must be considered. This source was discovered during World War II in connection with an interference project involving a particular military vehicle. All approaches apparent to the engineers working on the project had been taken. Yet one component of noise in the range of 140 megacycles remained at an unsatisfactory level. Since all of the usual procedures had been tried, it was decided that some new source was being encountered.

A complete analysis of the generator was made in an effort to locate this new source. This examination indicated that

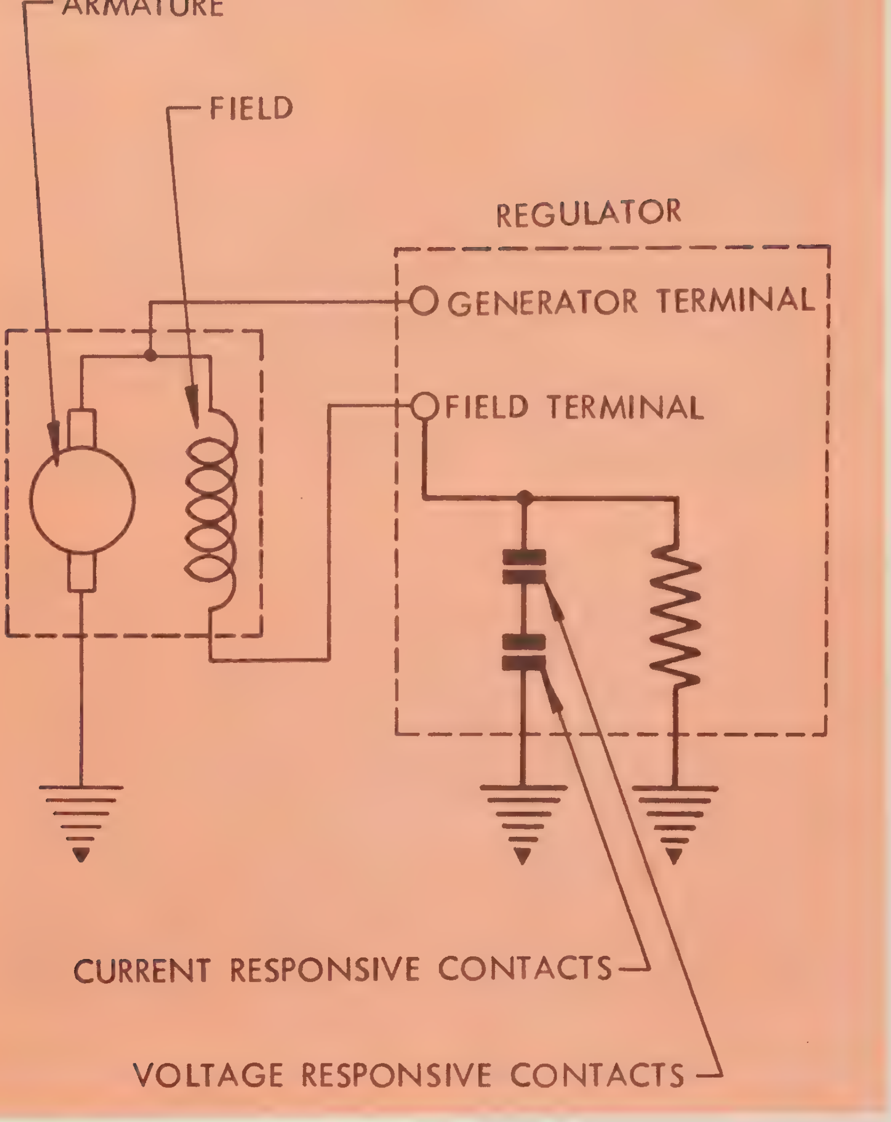


Fig. 8—Partial circuit diagram of a charging circuit.

the generator included all of the necessary parts of a Van de Graaff machine. The armature shaft and core are insulated completely from the frame of the generator by the lubrication in the bearings. During rotation this mass of material accumulates charge until its potential becomes sufficient to break down the film of grease. When breakdown occurs, the entire generator acting as a cavity resonator determines the frequency of the interference. This source of interference was eliminated by grounding the shaft by means of a series of brushes located at the drive end of the machine.

At the present time, nearly every generator that Delco-Remy Division supplies for use by the armed services has such a grounding system on the armature. There are indications that this suppression step should be included in the generator when that device is used in vehicles having high-frequency telephone installations. Such a procedure also is recommended for use in police automobiles and in small personal aircraft.

The regulator is called upon to accomplish a very difficult job. It is the function of this device to limit the generator output voltage to a value that will not damage the storage battery. It also must limit the amount of current to such a value that it will not burn out the generator windings. Subject to the above limitations, it must permit the generator to deliver the maximum amount of current to the car electrical system. To accomplish these ends, sensing devices are included inside the regulator. When either of the above limiting conditions appears, a resistor is inserted automatically in series with the generator field (Fig. 8).

An indication of how the insertion of resistance may give rise to steep wavefront voltages is given in the following example in which a group of conditions may be assumed. First, assume a generator terminal voltage of 7 volts. Then, specify the field resistance as 3.5 ohms. Then, further assume that the resistance to be inserted by the regulator has 30 ohms. An analysis of these conditions shows that the current flowing in the field circuit, at the instant before the resistor is inserted, is 7 divided by 3.5, or 2 amp. At the instant the resistor enters the circuit, the inductance of the field prevents the current from changing, so that the current of 2 amp then flows through 30 ohms and, instantaneously, a voltage of 60 volts is produced. Were it possible to use a capacitor across this resistor and its accompanying contact points, a great reduction in noise could be obtained. This condition is not possible since the condenser will cause serious contact transfer, with resultant short life.

Adequate suppression has been obtained by inserting coaxial condensers in the regulator-to-generator armature lead and in the regulator-to-battery lead. In some cases, the regulator engineers have permitted the use of a 0.002-microfarad condenser in series with a 4-ohm resistance across the regulator contact points.

When complete shielding is necessary in a particular installation, a shielded terminal enclosure is mounted on the generator and on the regulator, and heavy braided shields are used over the leads between the two units.

Conclusion

Very satisfactory operation can be achieved by applying the steps described in this paper. At the present time, the degree of complexity dictated by the different applications requires a variation in approach from the use of a single capacitor to application of all of the devices discussed.

The interference to radio and television services caused by automotive electrical equipment can be reduced to any prescribed level by the application of fundamental electrical theory. An understanding of electric and magnetic fields, combined with a knowledge of the a-c circuit under transient and steady-state conditions has made it possible for the engineer to solve all of the interference problems that have been encountered to this time.

General Motors Automotive Engine Test Code

By RALPH A. RICHARDSON,[*]
Secretary
Engine Test Code Subcommittee
General Technical Committee

Establishing a common baseline for testing to insure accuracy

A new fourth edition of the well-known General Motors Automotive Engine Test Code recently has been printed. This Code is used in dynamometer testing of four-stroke-cycle automotive engines by all General Motors automotive Divisions. It also is used by supplier and other cooperating laboratories. Many copies have been supplied to college and university engineering staffs as a teaching aid in internal-combustion engine courses.

The General Motors Automotive Engine Test Code grew out of a Research Laboratories project started in May 1927. At that time it was recognized that there was great confusion when engine tests made in one General Motors laboratory were compared to those made in another (Fig. 1). Each Division employed its own methods of conducting tests and computing the results, using equipment and instrumentation in a manner suitable to its own judgment. As many or as few of these data were presented in curves as seemed desirable in the opinion of the engineer in charge.

To obtain acceptance of uniform standards of engine testing throughout General Motors, a temporary committee was organized in 1928. After meeting for two years, it was organized as a permanent subcommittee of the General Technical Committee which is made up of the chief engineers of the Divisions with Mr. Charles A. Chayne, the vice president in charge of the General Motors Engineering Staff, as its chairman.

The membership includes representation as follows from the engineering laboratories of

Buick Motor Division—
  E. E. Hartz
Cadillac Motor Car Division—
  J. B. Richardson
Chevrolet Motor Division—
  A. J. Underwood
Oldsmobile Division—
  R. C. Bird
Pontiac Motor Division—
  E. L. Windeler
General Motors Truck and Coach Division—A. D. Buchanan
General Motors Engineering Staff—
  Stephen Kalmar, E. C. Campbell
Research Laboratories Division—
  R. A. Richardson, A. D. McDuffie, E. J. Martin
Delco-Remy Division—
  G. O. Huntzinger
Harrison Radiator Division—
  G. H. Knox
Rochester Products Division—
  H. H. Dietrich

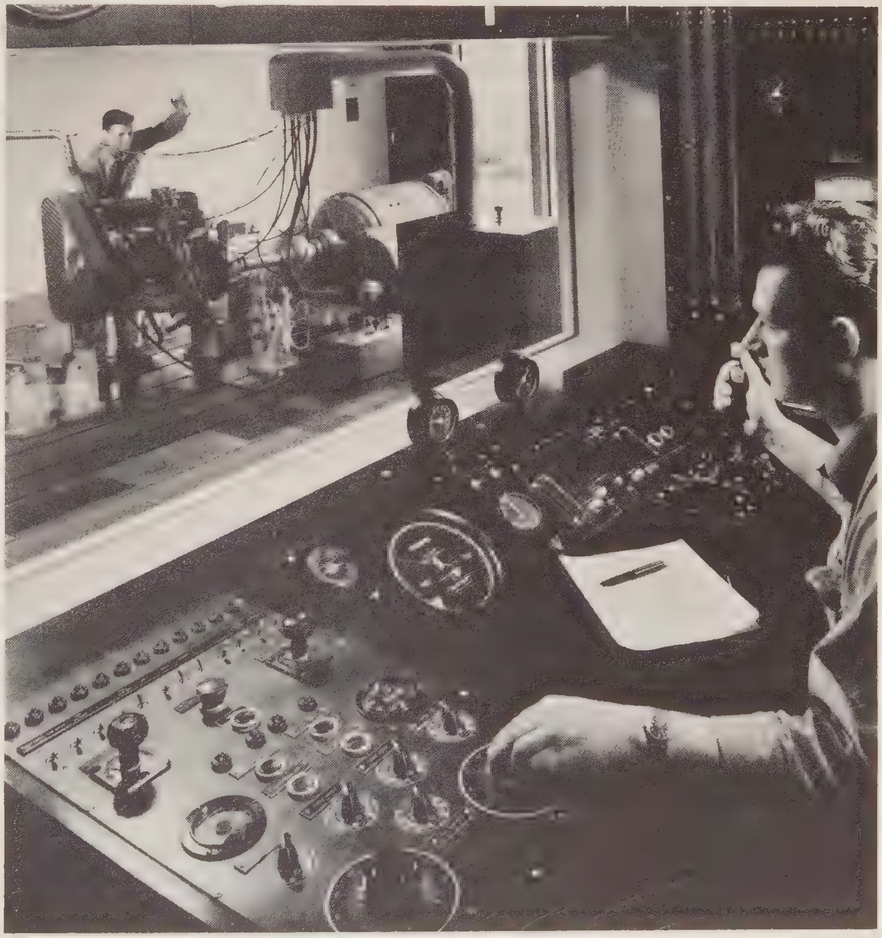


Fig. 1—By standardizing engine installation, equipment, and testing procedures, the Code establishes a common baseline for the testing of automotive engines. Thus, although the test shown above is being conducted at the Research Laboratories Division, the information obtained can be compared directly with the results of tests run by any other Division of General Motors.

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[*] For photograph and biography, please see p. 65 of June-July 1953 GENERAL MOTORS ENGINEERING JOURNAL. This is the third contribution to the JOURNAL by Mr. Richardson, head of the Administrative Engineering Department, Research Laboratories Division.

Fig. 2—Although most of the Code is concerned with engine testing, one section is devoted to the measurement of carburetor-flow characteristics. Use of the Code standards helps in evaluating the performance of experimental carburetors such as the one shown within this carburetor metering tank.

Detroit Diesel Engine Division—
G. P. Berry
General Motors Institute—
H. W. Reese
General Motors Proving Ground—
K. A. Stonex.

Code standards formulated by the Engine Test Code Subcommittee are submitted to the General Technical Committee for approval.

Previous Editions

The first tentative Code was printed in 1929 with a revision in 1930. The permanent approved Code was printed in 1933. After seven years of use, advances in engineering, instrumentation, and test methods made it desirable to review the Code and make suitable revisions. The work resulted in the revised Code printed in 1940. Immediately after the war, meetings were held again and change sheets were printed in 1946 to bring the 1940 edition up-to-date.

The Current Code

In 1953 another revision was completed. This is known as the fourth edition and supersedes all others now in use. This edition is a cloth-bound volume of 157 pages.

The Code is divided into six parts to make it easy to use. The major sections of the Engine Test Code are:

I General Code Information
II Standard Engine Tests
III Carburetor-Flow Test [Fig. 2]
IV Cold-Room Tests
V Power-Correction Tables
VI Checking Lists and Abbreviations.

The Foreword sets forth its purpose and aims as the Test Code Subcommittee sees them:

> The General Motors Automotive Engine Test Code provides uniform standards for conducting tests on spark-ignition automotive engines. It also provides a uniform method of presenting the data from these tests. When it is used, results obtained in one laboratory are directly comparable to those obtained in another. Tests made in the past are also directly comparable to current test results.

Part I, General Code Information, lists the information necessary for running any test in accordance with the Code requirements. It minimizes test-setup variations by specifying which optional engine equipment should be used and the manner in which this equipmen should be connected. Further standardization is achieved by specifying the pick-off points for measuring appropriate pressures and temperatures. This firs section also includes recommendations for specific types of instrumentation and a discussion of the precision required.

Another important feature of Part I is the material on computations. Equations and background material covering computations of torque, correction factors, and fuel consumption are presented in considerable detail. Similar information for computing heat-distribution and air-consumption values is included as part of the test write-ups, since these calculations are required only in the particular tests with which they are associated.

Even with all this detail, the Subcommittee has not forgotten that research and development cannot be standardized; therefore, anything that would hamper freedom of thought has been left to the engineer's judgment. This emphatically does not mean that the general recommendations and procedures cannot usually be followed in this type of work; it means only that all types of test procedures have not been standardized.

Part II lists the 21 standard-type tests covered by the Code. This section follows in general, the standard tests in previous editions. However, two new tests have been added and all have been rewritten to clarify the procedures and explanations. The standard tests are as follows

Test No.	*Title*
1.	Full Throttle as Installed
2.	Muffler
3.	Full-Throttle Power with MBT (Minimum for Best Torque) Spark and Fixed Carburetor
4.	Full-Throttle Power with MBT (Minimum for Best Torque) Spark and LBT (Leanest for Best Torque) Carburetor
5.	Blow-By
6.	Spark-Timing Sensitivity
6A.	Maximum Power and Spark-Timing Sensitivity with Non-Knocking Fuel
7.	Maximum Power and Detonation
8.	Full-Throttle Power and Economy
9.	Heat Distribution
10.	Volumetric Efficiency as Installed
10A.	Volumetric Efficiency, Maximum Power
11.	Motoring Friction
12.	Motoring Compression

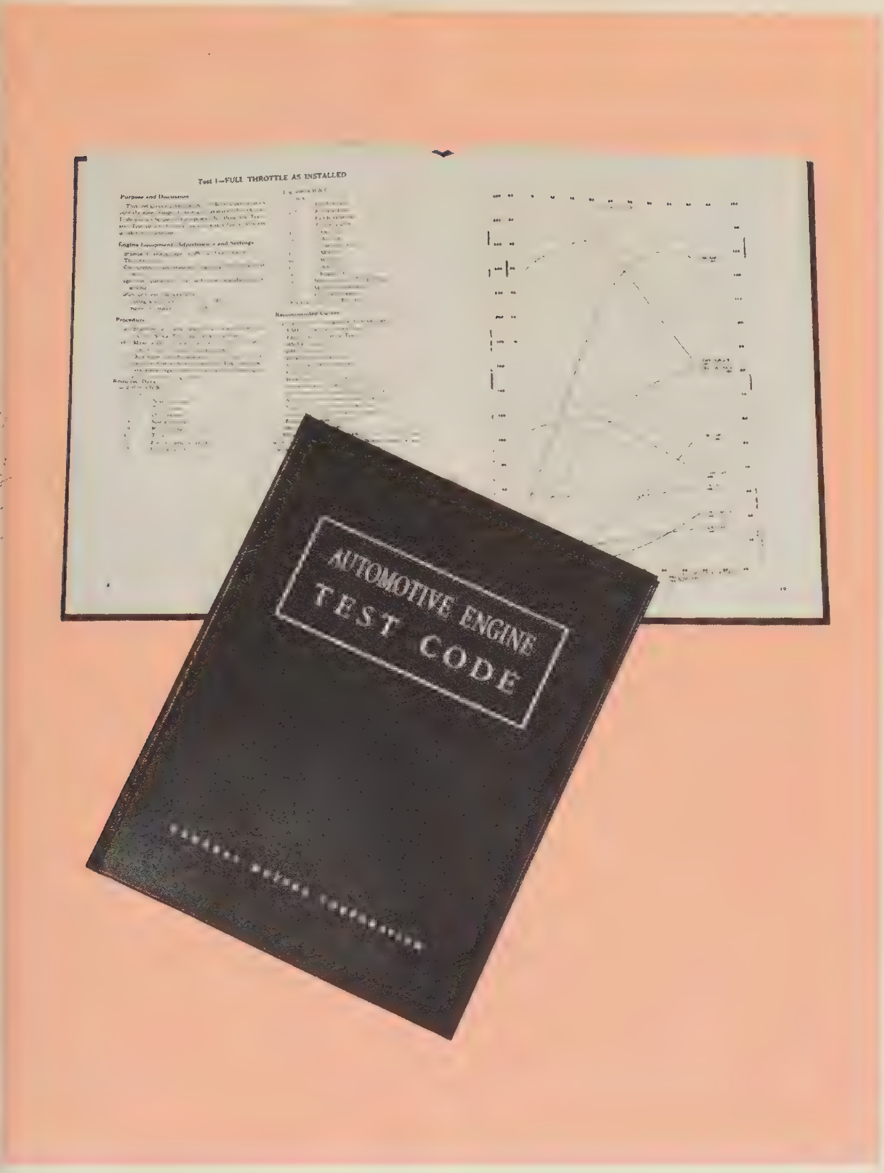


Fig. 3—The layout of most of the tests within the Code is similar to that shown here. Each test write-up contains complete information for running the test and samples of all recommended curves.

13. Fuel Distribution—Temperature Method
13A. Fuel Distribution—Gas-Sample Method
14. Oil Consumption
15. Road Power as Installed
16. Road Power, Best-Economy Spark
17. Road Power, Best Economy
18. Economy at Fractional Loads, as Installed
19. Stock-Engine Test

Sample curves, as called for in the type test, are included in the Code (Fig. 3). These help in obtaining more uniform plotting of data and, of course, make results easier to compare directly. Wherever necessary, test-procedure curves have been included to help in understanding the procedure instructions.

An important section of Part II is the Stock-Engine Test, listed as Test 19. The Purpose and Discussion states the aim of this test as follows:

> This is a program of tests in which the conditions to be met, tests to be made, information to be supplied, and outline to be followed in presenting results are governed by definite and uniform standards of the Code. It is recognized as a comprehensive test for any engine and is to be made on each new model stock engine placed on the market by the Corporation. The purpose is to obtain a fund of like and comparable information on engine performance.

Part III gives the Carburetor Flow Test, and includes a standard flow sheet and method of plotting. In formulating this test, the Subcommittee was aided by the carburetor engineers of the Divisions. Its use is an aid in obtaining comparable results from one flow bench to another.

Part IV gives general requirements for running cold-room tests. A cold-starting test procedure and a cold-cranking test procedure are detailed. The use of these procedures has been of great assistance in making cold-room tests more useful and comparable. The construction of many more cold rooms in the Divisions has made this section necessary.

Part V contains all of the tables and reference material needed to run the standard tests and correct the observed data. It includes curves for determining dry barometric pressure and tables of correction factors for correcting observed power readings to standard conditions of temperature, pressure, and humidity. The tables are compiled for both brake and indicated power.

This section also includes tables and curves showing the relationship of air-fuel ratio to exhaust-gas composition—information necessary in one type test.

Part VI, the last section, is made up of checking lists and a tabulation of Test-Code abbreviations. The checking lists summarize the data and curves called for by each test and thus have considerable value as an index.

Availability of Code to Engineering Faculty Members

Members of the faculties of engineering colleges and universities may obtain a copy of the fourth edition of the General Motors Engineering Test Code gratis by writing to:

RALPH A. RICHARDSON,
Head
ADMINISTRATIVE ENGINEERING DEPARTMENT
Research Laboratories Division
General Motors Corporation
Post Office Box 188,
North End Station
Detroit 2, Michigan

Notes About Inventions and Inventors

By **CARL F. SIBBE**
Patent Section
Central Office Staff

New devices for new results—and for old results in a better way

INVENTION has been defined in various ways but, in the broad sense, it generally is understood to be the creation of something which did not exist previously. It does not include the revelation of something which exists but was unknown. The discovery of a law of nature or a scientific principle, therefore, is not regarded as constituting invention even though it had remained unknown until revealed by the one making the discovery. Invention is the requirement which constitutes the foundation of the right to obtain a patent—the other requirements being that the invention must be (a) new, (b) useful, (c) fully disclosed, and (d) must never have been abandoned.

What Must Be Done to Complete an Invention?

In order to satisfy the statutory requirements governing the grant of a patent, the invention must be *reduced to practice.* The inventive idea alone is insufficient, no matter how completely it may have been formulated in the inventor's mind. It also must be presented in some physical form and proven to be successful or embodied in a patent application and filed at the United States Patent Office before the invention is recognized as having been completed.

Certain definite acts must be performed before the actual reduction to practice of an invention is recognized. For example, if the invention is to be applied to an automobile it must be installed on an automobile and must perform successfully under operating conditions to satisfy the requirements regarding an actual reduction to practice of such a device. Thus, either an actual reduction to practice of an invention or the filing of a patent application, which is considered to be a constructive reduction to practice, constitutes a satisfactory method of *completing* an invention.

What If Two Inventors Claim the Same Invention?

It often happens that two or more persons, working entirely independently of each other, may make the same invention. Since a patent may be granted only to the first inventor, when two or more applications embodying such an invention are co-pending in the Patent Office, an *interference* is declared and a definite procedure, regulated by the Rules of Practice of the Patent Office, is followed to determine the first inventor.

The burden of the proof is on the inventor whose application was filed last. If the inventor who filed last was the first to conceive the invention, in order to be successful in the interference, he must prove that he worked diligently towards reducing his invention to practice from the time just prior to the conception date of the other invention until his own invention was either physically reduced to practice or until his application was filed in the Patent Office. Hence, if the inventor whose application was filed last is unable to prove such diligence then the other party will be awarded the patent even though his conception of the invention was later. It, therefore, is important to exercise the utmost diligence in completing the invention by reducing it to practice by either or both of the methods described.

Patentable Inventions

The line of demarkation between invention and non-invention often is difficult to ascertain. Generally speaking, if the new device produces a new result or an old result in a new or more efficient manner, it is regarded as involving invention and may be patented.

There are a number of rules that may be employed to test the patentability of a new invention. Like most other rules, there are a number of exceptions and, consequently, there is no definite test that could be applied with any degree of certainty to all situations. Each invention, therefore, should be considered on its own merits and, even though the device constituting the new invention may not be materially different from other known devices, the differences between them may be highly significant in so far as the results obtained are concerned and may fully satisfy the requirements relating to patentable inventions.

Since invention is the creation of something which did not previously exist, the disclosure of an invention contained in a patent adds to the knowledge of the world. The patent bears the name of the inventor and is a permanent record of his achievement. Copies of United States patents are on file in most countries throughout the world and constitute a source of invaluable information. Patents, therefore, not only benefit the inventor or his employer but also benefit the public-at-large since it has access to an ever-growing wealth of information. After expiration of a patent the public may adopt the invention disclosed therein in its entirety. It is because of such benefits that flow to the general public that our patent system was founded.

Patents Granted

On this and the following pages are listed some of the patents granted during the period from September 15 to November 30, 1953. The brief patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each patent.

- **Godfrey G. Kearful,** *Saginaw Steering Gear Division, Saginaw, Michigan, for an Electric Windshield Wiper, No. 2,651,802,* *issued September 15.* This patent is directed to an electrical windshield-wiper drive mechanism having a novel cam interconnection between the motor shaft and the crank arm so that reversing the direction of rotation of the motor displaces the crank arm radially, thereby operating an electric switch which stops the wiper motor in the parked position.

Mr. Kearful serves as plant and process engineer at Saginaw Steering Gear. Mr. Kearful studied electrochemical engineering and engineering administration at Massachusetts Institute of Technology. He was employed by AC Spark Plug Division, Flint, Michigan, in 1927 as a specifications clerk in the Product Engineering Department and was promoted to product-design draftsman and, later, to inspection foreman at this Division. In 1938 he transferred to Saginaw Steering Gear Division as a methods engineer and, subsequently, he served in a number of capacities in plant engineering and manufacturing work including master mechanic and supervisor of process development. Mr. Kearful has authored a paper entitled "Electrolytic Production of Chromate from Ferrochromium Anodes" appearing in the proceedings of the Electrochemical Society.

- **Albert A. H. Kenlock,** *Vauxhall Motors, Limited, Luton, England, for a Connector Strip, No. 2,655,239, issued October 13.* This patent relates to sealing strips for use in the assembly of windshields to automotive bodies and particularly to clip members provided for engaging a portion of the strip, the clips acting as attaching means for a garnish molding.

Mr. Kenlock serves as passenger-body engineer at Vauxhall Motors, Limited. He was employed by Vauxhall Motors in 1929 as a detail draftsman and was promoted through the positions of layout draftsman, leading draftsman, section leader, and assistant passenger-body engineer. He was appointed to his present position in 1947. He presently is concerned with the "E" series of Vauxhall passenger vehicles. This is the first United States patent granted as a result of Mr. Kenlock's work with passenger-vehicle body details. He has authored a paper on pressed-steel automotive bodies.

- **William D. Carson and Alva L. Hindall,** *Delco-Remy Division, Muncie, Indiana, for a Method and Apparatus for Curing Positive Storage Battery Plates, No. 2,656,399, issued October 20.* This patent relates to a method for curing positive-pasted plates for lead storage batteries and is directed to a continuous heating process in a moisture-laden atmosphere wherein the atmosphere is maintained in a static condition.

- **William D. Carson and Alva L. Hindall,** *Delco-Remy Division, Muncie, Indiana, for the Manufacture of Negative Plates, No. 2,656,400, issued October 20.* This patent deals with a method for manufacturing negative-pasted plates for lead storage batteries wherein the plate is cured in a moisture-laden atmosphere in two stages, the first without pressure and the second under a pre-determined pressure of steam.

Mr. Carson serves as general foreman in the Delco Battery Operations Plant at Muncie. After earning the B.S. degree from East Tennessee State College in 1937, he joined Delco-Remy as a routine chemist in the Engineering Laboratory. He was promoted to chemist in 1939, to battery tester in 1940, to process engineer in 1945, and to his present position, general foreman, in 1953. Among the previous projects on which Mr. Carson has been engaged are the development of curing ovens for battery plates, improvement of lead-oxide manufacturing, and the development of continuous permanizing equipment. This is the fifth patent granted as a result of Mr. Carson's work in the field of engineering and processing.

Mr. Hindall is a consultant in the Delco Battery Operations, Muncie plant. Mr. Hindall has been with Delco-Remy since 1928 when he joined the Division as chief chemist. In 1935 he transferred to the X-ray and Development Laboratory and shortly afterward was made assistant director of the Laboratory. He continued in this post until 1941 when he was made director of battery research and development. Six patents for improvements in storage battery plates have resulted from his work. Some of his previous projects have included the application of X-ray diffraction to storage-battery problems and processes for curing and forming battery plates. Ohio State University granted him the B.A. degree in 1918. His technical affiliations include membership in the Electrochemical Society.

- **Adolph F. Braun,** *Buick Motor Division, Flint, Michigan, for an Anti-stall Device, No. 2,657,037, issued October 27.* This patent covers a diaphragm device for preventing the throttle of an engine from closing too quickly and stalling the engine. Valve means is provided for rapidly admitting and slowly exhausting atmospheric air to and from one side of the diaphragm as the diaphragm moves in opposite directions.

Mr. Braun's biography was published previously on page 51 of the January-February 1954 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

- **William D. Chilton,** *Fisher Body Division, Detroit, Michigan, for a Hog Ring Clinching Tool, No. 2,656,539, issued October 27.* This patent relates to a power hand tool for closing or clinching hog rings which are used to attach seat trim to seat frames and the like. The tool holds the ring gripped so that it can engage and pull the work into place and closes the ring by actuation of a trigger.

Mr. Chilton's biography was published previously on page 55 of the November-December 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

- **Clovis W. Lincoln, Ralph A. Malone, and Philip B. Ziegler,** *Saginaw Steering Gear Division, Saginaw, Michigan, for a Direction-Signal Switch, No. 2,657,287, issued October 27.* This invention relates to a manually set and automatically cancelled direction-signal switch mechanism. In the patented construction, a unitary member provides for signal cancelling in either direction as well as permitting inadvertent or intentional manual restraint without damage to the mechanism.

Mr. Malone is a designer in the Product Engineering Department of Saginaw Steering Gear. Employed by this Division in 1942 as a junior tool designer, he was promoted to senior tool designer in 1943 and to his present position in 1948. Mr. Malone's previous work with steering, transmission controls, and signal switches has resulted in four patents. Presently, he is concerned with advancements in power steering. Mr. Malone is a member of the Society of Automotive Engineers.

Mr. Lincoln's and **Mr. Ziegler's** biographies were published previously on page 53 of the November-December 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

- **Max G. Bales,** *Delco-Remy Division, Anderson, Indiana, for an Ignition System, No. 2,658,155, issued November 3.* This patent deals with an ignition system for an internal-combustion engine wherein, through the use of a unidirectional

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

electric valve, it is possible to supply greater current to the ignition coil than to the battery. This system is desirable particularly for use in connection with high-compression engines.

Mr. Bales' biography was published previously on page 52 of the September-October 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

- **Kenneth E. Bondurant,** *Delco-Remy Division, Anderson, Indiana, for a Terminal, No. 2,658,130, issued November 3.* This patent is directed to an improved sealed terminal for use in electric switches and the like wherein a moisture-proof joint between the terminal and the switch casing is desired.

Mr. Bondurant is project engineer at Delco-Remy. His association with this Division covers a period of thirty years during which he has been engaged in processing, tool design, and, more recently, product-design work. He began as a blueprint operator in 1923 and soon advanced to draftsman. In 1927 he was enrolled in the cooperative engineering program at General Motors Institute from which he graduated in 1932. Subsequently, upon completion of the Fifth Year and Thesis Programs, he received his degree. In 1932 he was transferred to the Process Department and one year later became foreman of production. He was made senior checker in 1936 and continued in this post until appointment to his present position in 1948.

- **Harry F. Clark,** *Frigidaire Division, Dayton, Ohio, for an Electrical Apparatus, No. 2,658,175, issued November 3.* This patent relates to the bi-metal-type starting and overload control used on split-phase motors in Frigidaire household refrigerators and includes an improved reset bi-metal heated by the main winding current to hold the phase-winding contacts closed for longer starting periods when the rate of motor acceleration is slower.

Mr. Clark is senior project engineer in the Household Engineering Department of Frigidaire. After earning the electrical engineering degree from University of Cincinnati in 1921, Mr. Clark was employed by the General Motors Research Corporation in Dayton (now called the Research Laboratories Division) as a research engineer in the Electrical Department. In 1925 Mr. Clark joined Frigidaire as a test engineer and after a series of promotions became senior project engineer in 1947. A considerable portion of his technical work has been related to motor and control apparatus, and during World War II he was engaged in electronic research on guided missiles. Twelve patents in the fields of electrical, mechanical, and refrigeration engineering have resulted from his designs. He is a member of the Engineers Club of Dayton.

- **Harold V. Elliott,** *Delco-Remy Division, Anderson, Indiana, for an Ignition Timer, No. 2,657,556, issued November 3.* The invention claimed in this patent is directed to an ignition timer for an internal-combustion engine wherein the usual speed-responsive adjustment means is of a modified construction.

Mr. Elliott is project engineer at Delco-Remy. His GM employment began in 1936 as a blueprint operator in Delco-Remy's Engineering Department. Shortly afterward, he transferred to the Model Shop. During this period he was enrolled as a cooperative engineering student at General Motors Institute. He graduated from G.M.I. in 1938. In 1941 he became a laboratory technician and a year later entered military service with the U.S. Navy. He served for a three-year period during World War II and again during 1950-1951. He was with the Research Laboratory at Delco-Remy from 1948 to 1950 and was appointed to his present position in 1951. This is the first patent resulting from Mr. Elliott's work with ignition devices.

- **Anton F. Erickson,** *Moraine Products Division, Dayton, Ohio, for a Seal, No. 2,657,825, issued November 3.* This patent relates to a packing seal to seal the parting line between two engageable members. The feature of the invention resides in a wedge-type of seal maintained under pressure.

Mr. Erickson is assistant supervisor of the Engineering Laboratory, Moraine Products. He was employed by Delco Brake Division in 1937 as a brake engineer. In 1939 he was promoted to foreman of the Laboratory and Experimental Garage, and in 1942, when Delco Brake merged with Moraine Products Division, he was made general foreman of the Production Machining Department. In 1943 he was transferred to the Metal Powder Department and was promoted to his present position in 1944. This is the tenth patent granted as a result of Mr. Erickson's work with aircraft and automotive components. He is a member of the Society of Automotive Engineers.

- **Howard M. Geyer,** *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Synchronized Power Transmitter, No. 2,657,539, issued November 3.* This patent relates to means for synchronizing the operation of a plurality of actuators, each actuator including a cylinder and a piston. The actuators are synchronized by means of a shaft which is interconnected with the piston of each actuator through the ball-screw and nut coupling.

- **Howard M. Geyer,** *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Dual Drive Actuator, No. 2,660,026, issued November 24.* This patent relates to an actuator which may be operated by either fluid pressure or an electric motor. The principal feature of the invention resides in the use of releasable locking means for maintaining the actuator in any adjusted position, the locking means being associated with a rotatable screw shaft forming part of the actuator.

- **Howard M. Geyer,** *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Dual Drive Actuator, No. 2,660,027, issued November 24.* This patent relates to an actuator which may be operated by either fluid pressure or an electric motor. The principal feature of the invention resides in the use of releasable locking means for maintaining the actuator in any adjusted position, the locking means being associated with the nut of a ball-screw and nut coupling forming part of the actuator.

- **Howard M. Geyer,** *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Dual Drive Actuator, No. 2,660,028, issued November 24.* This patent relates to an actuator which may be operated by either fluid pressure or an electric motor. The principal feature of the invention resides in the use of releasable locking means for maintaining the actuator in any adjusted position, the locking means being associated with the nut of a ball-screw and nut coupling forming part of the actuator, the screw shaft being capable of rotation by the electric motor.

• **Howard M. Geyer,** *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Dual Drive Actuator, No. 2,660,029, issued November 24.* This invention relates to an actuator having a cylinder with a pair of pistons disposed therein capable of simultaneous movement in opposite directions by either fluid pressure or by operation of an electric motor. The actuator also includes locking means for maintaining the actuator in any adjusted position thereof.

Mr. Geyer's biography was published previously on page 53 in the September-October 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **Thomas L. Kendall,** *Delco-Remy Division, Muncie, Indiana, for a Vent Cap, No. 2,658,100, issued November 3.* This patent relates to a vent cap for a storage battery wherein the cap is made of resilient material thereby eliminating the use of threads.

Mr. Kendall's biography was published previously on page 51 of the September-October 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **Raymond F. Kruszona,** *Fisher Body Division, Detroit, Michigan, for an Anchoring Means for Wavy Wire-Spring Ends, No. 2,657,738, issued November 3.* This patent is directed to the means for mounting the ends of transverse, wavy wire-spring members in spaced longitudinal frame members of vehicle seat structures in such a manner as to effect a saving in assembly costs.

Mr. Kruszona is senior designer in the Drafting Department of Product Engineering at Fisher Body. He was employed by the Division in 1935 as a draftsman in his present Department. He was made process engineer in the Manufacturing Division of the Aircraft Section in 1944 and was promoted to his present position in 1945. Much of his design work has been concerned with doors for automobile bodies. Mr. Kruszona studied mechanical engineering at Wayne University, Detroit, Michigan. This is the first patent granted as a result of his work in automotive design.

• **Charles A. Nichols and A. E. Riggs,** *Delco-Remy Division, Anderson, Indiana, for a Breaker Arm, No. 2,658,129, issued November 3.* This patent is directed to an improved construction of a circuit-breaker arm used in a distributor for an internal-combustion engine.

Mr. Nichols' biography was published previously on page 51 of the September-October 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

Mr. Riggs is general foreman of the Model Shop at Delco-Remy. This is the first patent resulting from his work with devices for automotive ignition systems. Mr. Riggs has been with Delco-Remy since 1918 when he started as a tool grinder. He transferred to the Model Shop in 1920 and was advanced to assistant foreman of the Model Shop in 1928. He served in this capacity until 1933 when he was made general foreman, his present position.

• **Wilbur J. Oakley,** *Moraine Products Division, Dayton, Ohio, for a Master Cylinder with Compensating Valve, No. 2,657,537, issued November 3.* This patent relates to the master cylinder of a hydraulic brake system. The feature of the invention is the provision of a compensating valve operated by the master-cylinder piston to provide makeup fluid to the master cylinder from a reservoir.

Mr. Oakley is project engineer at Moraine Products. He was employed initially by the Division in 1939 as an apprentice draftsman. He entered Naval service in 1943 and was separated in 1946 with the rank of ensign, having served as an engineering division officer. He earned the B.S. degree in mechanical engineering from Massachusetts Institute of Technology in 1945 where he was elected to Sigma Xi. Following his military service, Mr. Oakley rejoined Moraine as junior layout man and was appointed to his present post in 1951. This is the first patent resulting from his work with power brakes and automatic brake adjusters.

• **Edwin F. Rossman,** *Delco Products Division, Dayton, Ohio, for a Shock Absorber, No. 2,657,770, issued November 3.* This patent relates to a shock absorber for use as a damper on a helicopter. The feature of the invention resides in locating the control valve of a special type within the central tube that carries the shock-absorber piston.

Mr. Rossman serves as a research engineer in the Engineering Department at Delco Products. Employed by this Division in 1927 as a shock-absorber engineer, he became section engineer—shock absorbers in 1929, assistant chief engineer in 1936, chief engineer in 1940, and consulting engineer in 1945. During his career with Delco Products, Mr. Rossman has worked on the development of a ride levelizer, air suspension systems, and shock absorbers—all of which have led to 40 granted patents. Mr. Rossman earned the joint B.S. degree in mechanical engineering from Massachusetts Institute of Technology and from Harvard Engineering School in 1920. He is a member of the Riding Comfort Committee of the S.A.E.

• **Peter J. Bianco,** *Ternstedt Division, Detroit, Michigan, for a Spring Winding Machine, No. 2,658,267, issued November 10.* This patent covers a machine in which a reciprocating carriage receives a spiral spring from a stack or magazine at one end of its stroke and carries it opposite a perpendicular reciprocating ram whereupon the ram passes the spring through a helically slotted cylinder, while holding the innermost end of the spring from rotating, to a window-regulator assembly receiving it in wound condition.

Mr. Bianco is tool-maker leader in the Tool Room at the Detroit plant of Ternstedt. This is the first patent resulting from Mr. Bianco's work with tools and machines used in the manufacture of automobile-body hardware and accessories. His experience with tools and dies covers a period of more than twenty-five years. He has been with Ternstedt since 1928 when he started as a die maker in the Tool Room. He was advanced to his present position in 1939. His early technical education was received in Italy.

• **Franklyn P. Hegeman,** *Hyatt Bearings Division, Harrison, New Jersey, for a Grinding Machine, No. 2,660,006, issued November 24.* This patent relates to a grinding machine for grinding the thrust shoulder on the cone race ring of a roller bearing. This machine produces a self-generated spherical shape on the thrust surface which is desirable for bearing preloading.

Mr. Hegeman is assistant manager of the Process Development and Equipment Department at Hyatt Bearings. Employed by the Division in 1923 as an apprentice tool maker, he was promoted to machine designer in 1930. He became a project engineer in 1936 and continued in this capacity until 1947 when he was made supervisor of machine development. Two years later he was appointed to his present position. Mr. Hegeman's previous work on grinding and honing equipment has resulted in five patents.

Recent Speaking Engagements Filled by GM Engineers

Engineer-lecturers, speaking before technical societies and in engineering classrooms, are but one facet of General Motors' continuous program aiming at making available information on GM engineering developments to interested persons outside the organization. Listed below are some of the recent speaking engagements of GM engineers.

R. M. Schaefer, manager of the Transmission Engineering Department of Allison Division, appeared before the Indiana Section of the Society of Automotive Engineers in Indianapolis on December 3. The title of his talk was "The Effect of Torque Converters on the Design of Hydraulic Transmissions."

Stanford Landell, director of Product Engineering and Sales, Brown-Lipe-Chapin Division, discussed "The Look of Things" before The Technology Club of Syracuse, New York, on November 23.

At the Annual Meeting of the Society of Automotive Engineers held in Detroit on January 11, **Carl F. Joseph,** technical director at Central Foundry Division, spoke on "Pearlitic Malleable Iron—Its Properties and Expanded Uses."

R. R. Goodwin, accessory engineer in the Accessory Engineering Department of Chevrolet Motor Division, spoke before the Student Chapter of the S.A.E. at the Detroit Institute of Technology on December 16. His subject was "Automobile Heaters—Past, Present, and ?."

Maurice Olley, director of research and development at Chevrolet Motor, described "The Evolution of a Sports Car—The Chevrolet Corvette" to the Student Chapter of the S.A.E. at the University of Michigan, Ann Arbor on January 6.

"The Corvette Plastic Body" was a talk given at the Annual Meeting of the S.A.E. held in Detroit on January 11. The speaker was **E. J. Premo,** assistant chief engineer in the Body and Sheet Metal Department of Chevrolet Motor.

Paul I. Bland, supervisor of the Statistical Quality Control Department at Delco Products Division, discussed "Statistical Quality Control Applications in Industry" before the Dayton, Ohio, meeting of the Research Component, U.S. Naval Reserve on January 11.

Kenneth L. Hulsing, chief application engineer in the Engineering Department at Detroit Diesel Engine Division, spoke to the St. Louis, Missouri Section of the S.A.E. on December 8. His subject was "Factors Influencing Operating Performance and Life of Diesel Engines."

Before the Metropolitan Section of the S.A.E. in New York City on January 7, **W. K. Simpson,** technical director of fuel and lubricants, Electro-Motive Division, discussed "Railroad Diesel Fuels of the Future."

Edward A. Reed, assistant chairman of the Industrial Engineering Department at General Motors Institute, spoke to the Product Engineering Section of the American Society of Mechanical Engineers in New York City on December 3. His topic was "Die Engineering."

Kenneth A. Stonex, head of the Technical Data Department at the General Motors Proving Ground, Milford, Michigan, spoke on "Automotive Test Track Design" before a graduate class in advanced highway design at the University of Wisconsin Extension School, Milwaukee on December 10.

Robert C. Waters, senior engineer in the Rubber and Plastics Laboratory of GMC Truck and Coach Division, spoke to the students of Marygrove College, Detroit on December 10. Mr. Waters discussed "Chemistry Applied to Automotive Products."

Donald J. LaBelle, senior project engineer in the Engineering Department of GMC Truck and Coach, described "Air Suspension" to the S.A.E. on January 5 in Cambridge, Massachusetts.

"Automotive Electrical Systems" was the title of the talk given by **Ralph H. Bertsche,** electrical engineer in the Electrical Engineering Department at GMC Truck and Coach, on January 7 before a joint meeting of the Society of Automotive Engineers, the American Institute of Electrical Engineers, and the American Society of Mechanical Engineers at Fort Wayne, Indiana.

On December 15 **L. D. Cobb,** manager of research and development in the Product Engineering Department of New Departure Division, described "Ball-Bearing Design and Manufacture" to the A.S.M.E. Student Branch at Pratt Institute in Brooklyn, New York.

At the University of Michigan, Ann Arbor on January 7, **F. H. Grady,** engineer—automatic transmissions, Engineering Department of Pontiac Motor Division, described the "Matching of Engine and Transmission."

Edward K. Benda and **Raymond A. Gallant,** research engineers in the Special Problems Department of the Research Laboratories Division, before a joint meeting of the Society for Experimental Stress Analysis and the American Society of Mechanical Engineers held in New York City on December 2, discussed "An Automatic Load Control for Fatigue Equipment."

In Detroit on January 12, **Raymond L. Mattson,** assistant head of the Engineering Mechanics Department of Research Laboratories, spoke before the S.A.E. His topic was "The Effects of Residual Stress on the Fatigue Life of Metals."

During the Society of Automotive Engineers meeting held in Detroit on January 14, five Research Laboratories personnel participated.

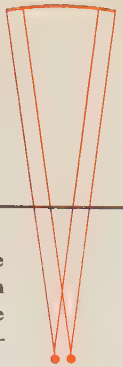
Darl F. Caris, head of the Automotive Engines Department, discussed "What Can We Get From Higher Octane Number Fuels?".

James R. Landis, research engineer in the Fuels and Lubricants Department, spoke on "Gasoline Additives."

Wayne A. Daniel and **Joseph T. Wentworth,** junior engineers in the Fuels and Lubricants Department, and **Donald R. Olson,** consultant, discussed "The Evaluation of the Energy Released During Pre-flame Reactions."

Norman A. Reilly, service engineer in the Service Department of Rochester Products Division, spoke before the National Hot Rod Association in Rochester, December 3, on "Engine Valve Timing and Its Influence Upon Carburetion."

A Typical Problem in Automotive Design: Plot the Ground Plans of Visibility from the Driver's Position In an Automobile



By REO S. BRINK
GM Proving Ground
Milford, Michigan

Two light bulbs plus mathematics determine driver visibility

When testing, evaluating, and comparing automobiles one of the items that should be evaluated is that of driver visibility. Blind spots that exist may cause accidents. Much has been done in the past few years to increase driver visibility. The use of one-piece windshields has come into wide use and the latest innovation to windshield design—the wrap-around front and rear window—has done much to increase visibility. A system has been in use at the GM Proving Ground at Milford, Michigan, for several years, in which the driver's visibility forward and to the rear may be plotted from vertical surfaces and projected to forward and rearward ground plans of visibility. The problem presented here is one which calls for plotting such a ground plan with data taken from an actual test.

THE system for determining driver visibility at the GM Proving Ground at Milford, Michigan, entails the use of two six-volt light bulbs located inside the car to simulate the eye positions of a person of average stature sitting in the driver's seat. The car is located in such a way that the mid-point between the two bulbs is on the vertical axis of a semicircular screen placed in front of the automobile. Fig. 1 shows a plan view of the visibility-test arrangement. The semicircular screen *F* is used in determining forward driver visibility and screens *A* and *B* are used in determining driver vision to the rear. Screen *F* is located at a radius of 12 ft from the mid-point between the two light bulbs and screens *A* and *B* are at a distance of 10 ft and 20 ft, respectively, from the mid-point. While making a test to determine driver's forward vision, a shield is placed behind the light bulbs to cut off any rays that might shine directly through the rear window. The rear-view pattern is obtained from the light reflected in the rear-view mirror.

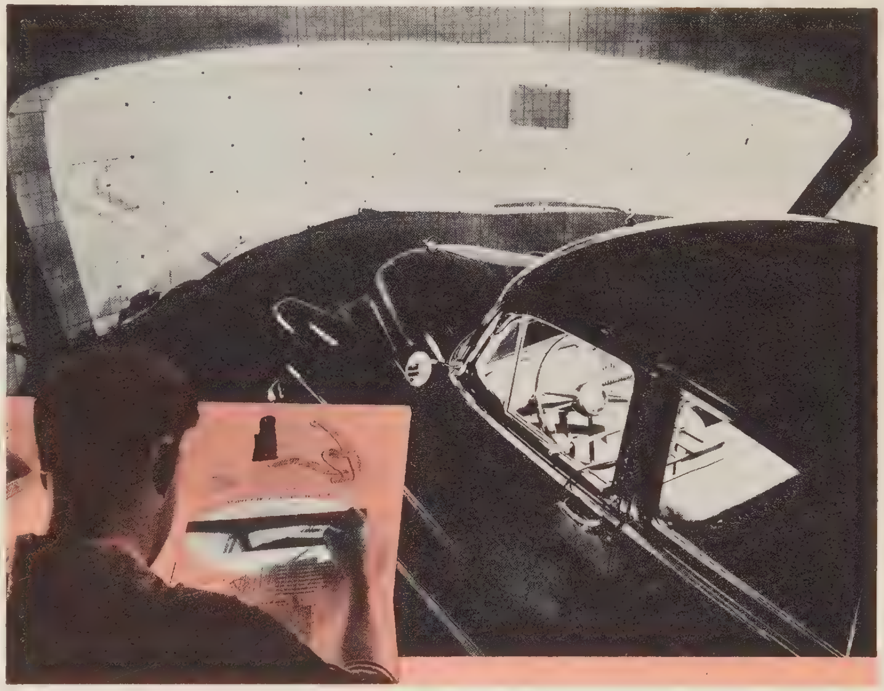


Fig. 2—Visibility test being conducted on a car in the visibility stall.

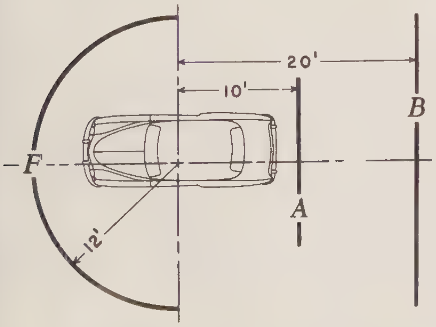


Fig. 1—Relationship of driver's eye position with screens *F*, *A*, and *B*.

Fig. 2 shows an actual test being performed in the driver visibility stall at the Proving Ground. Shown in the figure is a pattern formed on the semicircular screen *F*, which has vertical lines placed at one-degree intervals and extending 90° on each side of the straight-ahead position. Screen *F* also has horizontal lines which are placed at 0.2 ft intervals from the ground up to a height of 10 ft. Screens *A* and *B* are perpendicular plane surfaces and are similarly marked with horizontal lines at 0.1 ft intervals from the ground up and also at 0.1 ft intervals to the right and left of a vertical plane through the mid-point between the light bulbs and parallel to the car axis.

Fig. 3 shows a copy of a typical pattern plotted from screen *F*. The area of the figure with double crosshatching is that which cannot be seen by either eye. Patterns are obtained in a similar manner from screens *A* and *B* when the test is performed for rearward vision as shown in Fig. 4.

Fig. 5 shows an illustration of the

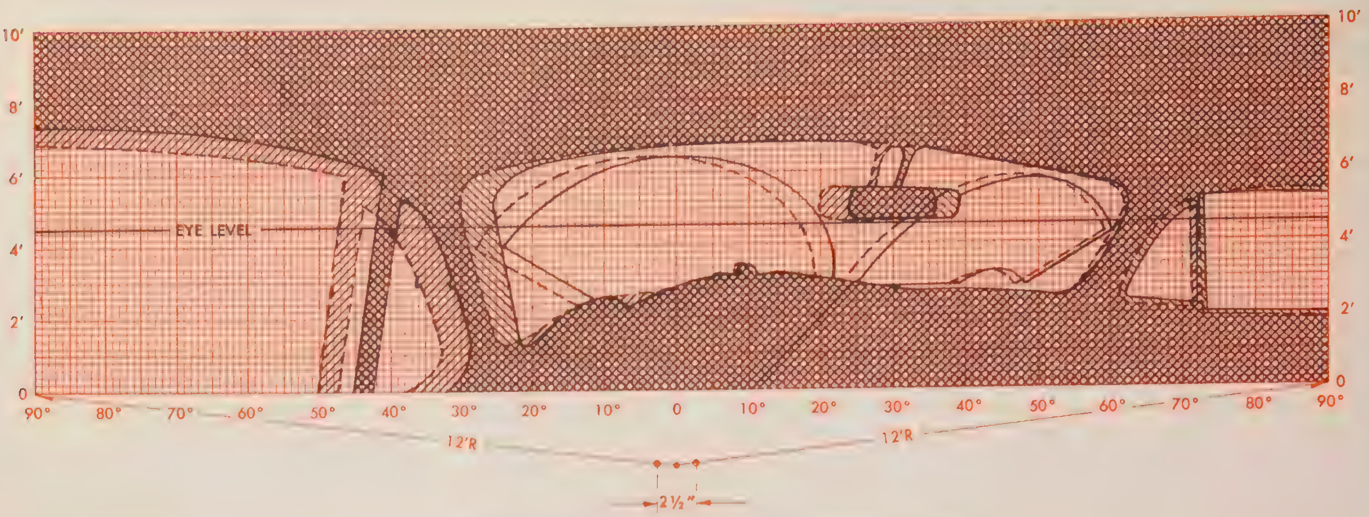


Fig. 3—Visibility from driver's position forward. Development of screen *F*.

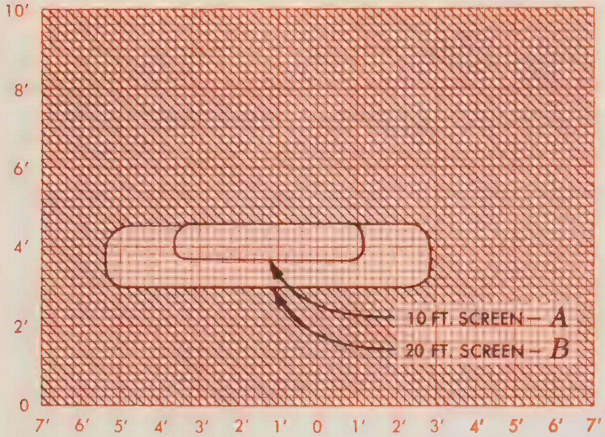


Fig. 4—Visibility from driver's position to the rear. Development of screens *A* and *B*.

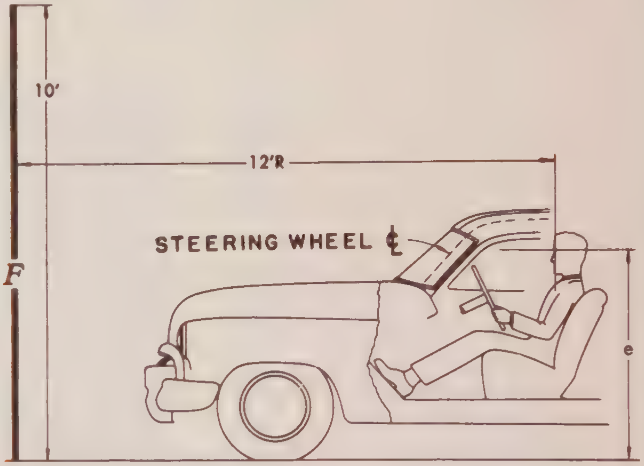


Fig. 5—Side view of driver in car and relationship of his eye position to the screen *F*.

average driver's position in the car and his relationship to screen *F*. The dimension *e* in the figure is the vertical dimension from the driver's eyes to the ground. For this problem, dimension *e* is 4.48 ft.

Table I shows a tabulation of points read from screen *F*. These points are used to compute the projections to the ground which result in the forward ground plan. The projections are plotted on a chart similar to that shown in Fig. 6, in which the distance ahead of the driver's position in the car should extend to 500 ft and to a distance of 200 ft on each side of the driver. In Table II, points read from screens *A* and *B* are tabulated. These points are used to compute the projections to the ground which result in the ground plan of the driver's vision through the rear-view mirror. Points for Table II were obtained from the patterns shown in Fig. 4. The ground plot for rearward vision is to be made on a chart similar to that used for forward vision, except that the diagram of the car should be reversed.

The projection of points from the pattern on screen *F* to the ground is greatly simplified by assuming that the value of the ground plot is not destroyed if the projection is made from the mid-point between the eyes, on the axis of the circular screen, rather than from the two points 2½ in. apart. To simplify the problem the windshield wiper pattern has been omitted from the tabulation in Table I and, therefore, may be omitted from the ground-plan plot.

Problem

All of the dimensions necessary to complete the problem are given. The problem is as follows:

> Determine the rectangular coordinates necessary to plot a plan of the driver's forward vision. The points that are tabulated in Table I are to be used in calculating the rectangular coordinates and the ground plan is to be drawn on a chart similar to Fig. 6. A ground plan also is to be plotted for the driver's rearward vision. The points tabulated in Table II are to be used to determine the rectangular coordinates necessary for this plot, which is to be done on a similar chart.

As in much test work, a knowledge of higher mathematics is not needed to solve this problem. A little knowledge of geometry and trigonometry, a pencil, a few sheets of data paper, perhaps a slide rule, two large sheets of graph paper, and a lot of patience are the requirements for making the projections and plotting the ground plans.

The answer to the problem will be published in the next issue of the General Motors Engineering Journal.

VISIBILITY FORWARD
POINTS READ FROM SCREEN F

ANGLE Degrees	SCREEN HEIGHT Feet
Left Ventipane Divider Strip	
−39.4	4.29
−39.3	4.25
−39.3	4.29
Left Ventipane	
−33.7	4.36
−33.6	4.29
−33.5	4.21
−32.8	3.94
−31.2	3.15
−31.7	3.00
−31.7	2.92
−31.0	2.92
−30.0	2.25
−29.0	1.60
−28.6	1.15
−29.2	0.60
−31.8	0.00
Windshield	
−29.3	4.36
−29.2	4.34
−29.1	4.21
−28.0	3.40
−26.0	2.00
−25.0	1.40
−23.0	1.30
−21.8	1.38
−21.0	1.25
−20.0	1.37
−17.0	1.80
−14.0	2.21
−10.0	2.53
−8.0	2.50
−6.7	2.30
0.0	2.82
+5.0	3.08
+8.7	3.18
Windshield (continued)	
+8.5	3.33
+9.1	3.41
+10.7	3.13
+12.0	3.13
+13.7	3.20
+15.0	3.10
+20.0	3.00
+26.0	2.82
+31.5	2.67
+40.0	2.63
+50.0	2.58
+53.8	2.43
+55.0	2.68
+57.0	3.02
+59.0	3.60
+60.5	4.02
+61.0	4.21
+61.1	4.29
+61.2	4.35
Right Ventipane	
+66.5	4.35
+66.3	4.32
+66.2	4.29
+65.9	4.21
+65.0	3.98
+63.0	3.40
+62.0	3.00
+61.3	2.60
+62.0	2.27
+63.0	2.22
+67.0	2.20
+71.5	2.13
+71.5	2.21
+72.2	2.20
+71.9	4.20
Right Window	
+72.2	4.20
+72.8	1.92
+80.0	1.86
+90.0	1.80

ble I—Visibility forward. Points read from screen *F*. he data in this tabulation may be used to compute location points on ground plan of driver's vision forward.

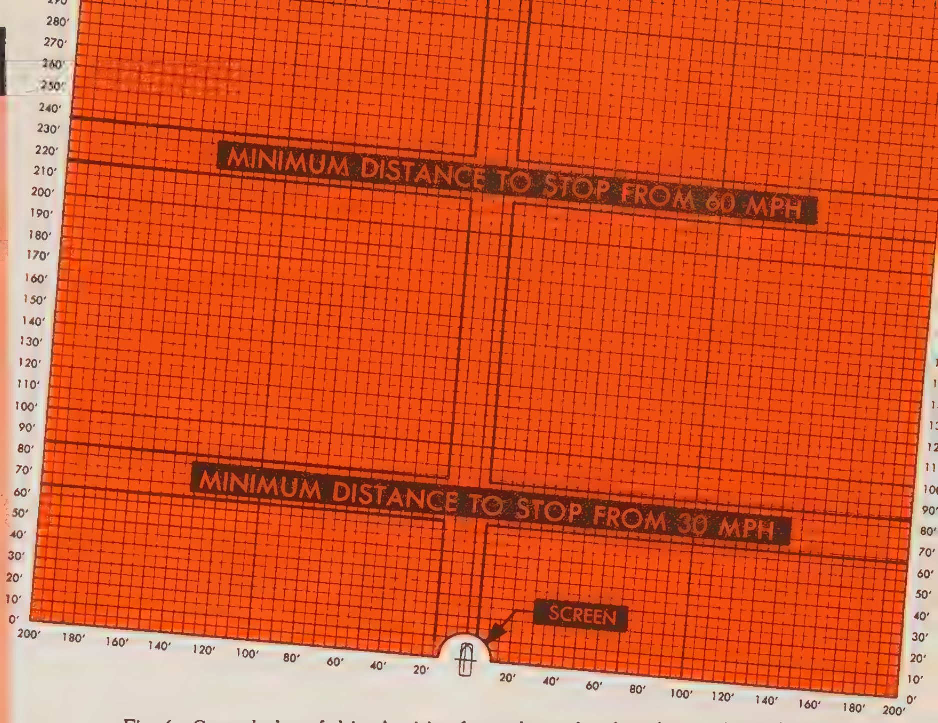


Fig. 6—Ground plan of driver's vision forward may be plotted on a chart of this type. The centerline of the chart passes through the mid-point between the driver's eyes. Street lines, while not a part of this problem, are shown to represent minimum stopping distances from 30 mph and from 60 mph. Ground plan of the driver's vision through the rear-view mirror may be plotted on a similar chart, omitting the street pattern but showing the car in a reversed position with the centerline of the chart passing through the mid-point between the driver's eyes.

VISIBILITY TO THE REAR
POINTS READ FROM SCREENS A AND B
FEET

	Vertical Height Above Ground		Horizontal Distance from Eye Centerline — to left; + to right	
Point No.	Screen *A* a	Screen *B* b	Screen *A* a′	Screen *B* b′
1	3.59	2.86	0.00	+0.83
2	3.60	2.89	+0.90	+2.40
3	3.70	3.08	+1.08	+2.69
4	3.90	3.40	+1.13	+2.80
5	4.10	3.73	+1.13	+2.80
6	4.30	4.10	+1.12	+2.78
7	4.46	4.36	+1.05	+2.64
8	4.55	4.51	+0.90	+2.48
9	4.56	4.51	0.00	+0.85
10	4.55	4.51	−1.00	−0.85
11	4.55	4.51	−2.00	−2.56
12	4.55	4.50	−3.00	−4.36
13	4.54	4.49	−3.40	−5.03
14	4.45	4.34	−3.56	−5.30
15	4.30	4.10	−3.62	−5.40
16	4.10	3.74	−3.63	−5.42
17	3.90	3.40	−3.62	−5.42
18	3.78	3.19	−3.60	−5.38
19	3.66	3.00	−3.40	−5.04
20	3.65	2.98	−3.00	−4.37
21	3.61	2.90	−2.00	−2.55
22	3.60	2.89	−1.00	−0.85

Table II—Visibility to the rear. Points read from screens *A* and *B*. The data in this table may be used to compute location of points on ground plan of driver's vision to the rear.

The Solution to Finding the Exhaust Valve Cone Angle for a Ball in the Dynaflow Transmission

By CLIFFORD C. WRIGLEY
General Motors
Engineering Staff

The ball unseats
at various
cone angles

One of the problems encountered in the designing of the Buick Dynaflow transmission was the determination of the exhaust valve cone angle for the *Buick Ball,* a steel ball in a conical seat over a coaxial exhaust hole. This angle must be within certain limits to allow the ball to operate as a valve by closing and opening the exhaust hole, allowing oil to escape. The problem was presented in the January-February 1954 JOURNAL. The mathematical solution shows that the angle α must be *greater than 32.5°* and *less than 50.5°* for the ball to remain seated to 4,500 rpm.

THE first step in finding the size of angle α is to solve for the exhaust valve cone angle using the conditions given in Fig. 1 and Table I. The transmission-line pressure applied at the inlet of the clutch is 90 psi and, together with the centrifugal pressure, must keep the ball seated up to 4,500 rpm. The ball must unseat itself against the centrifugal oil pressure when the line pressure is cut off. The effect of gravity on the ball may be neglected.

At the balance point of the ball unseating there are three forces acting on the ball (Fig. 2):

F_p = pressure force tending to seat the ball

F_c = the effective centrifugal force of the ball

F_r = the reaction force of the conical seat.

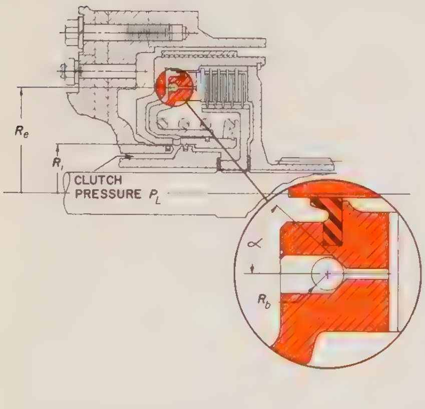


Fig. 1—Cross-sectional drawing of the Dynaflow transmission showing the location of the *Buick Ball.* The lower right-hand drawing shows the *Buick Ball* and ball seat magnified. R_e represents the radius of the centerline of the exhaust ball seat; R_i represents the radius of the feed line inlet to the clutch; P_L represents the line pressure applied to the clutch; R_b represents the radius of the exhaust ball; α represents ½ of the included angle of the conical ball seat.

The ball will balance when $F_c \sin\alpha = F_p \cos\alpha$ and will leave its seat if $F_c \sin\alpha > F_p \cos\alpha$.

The pressure force seating the ball F_p is a function of (a) the centrifugal pressure of the oil, (b) the transmission-line pressure in the clutch, and (c) the contact area of the ball on the seat:

(1) Centrifugal oil pressure $= \frac{w_1\omega^2}{2g}(R_e^2 - R_i^2)$

(2) Total oil pressure $= \frac{w_1\omega^2}{2g}(R_e^2 - R_i^2) + P_L$

(3) Seat contact area $= \pi(R_b \cos\alpha)^2$

$$F_p = \left[\frac{w_1\omega^2}{2g}(R_e^2 - R_i^2) + P_L\right]\pi(R_b \cos\alpha)^2. \quad (1)$$

The effective centrifugal force F_c on the ball is determined from the following:

A = centrifugal force of the ball in air $= \frac{w_2}{g}\frac{4}{3}\pi R_b^3 R_e\omega^2$

B = centrifugal force of displaced oil $= \frac{w_1}{g}\frac{4}{3}\pi R_b^3 R_e\omega^2$

$$F_c = A - B \quad (2)$$

$$F_c = \frac{(w_2 - w_1)}{g}\frac{4}{3}\pi R_b^3 R_e\omega^2. \quad (3)$$

Balance point of ball:

$$F_c \sin\alpha = F_p \cos\alpha \quad (4)$$

$$\frac{(w_2 - w_1)}{g}\frac{4}{3}\pi R_b^3 R_e\omega^2 \sin\alpha = \left[\frac{w_1\omega^2}{2g}(R_e^2 - R_i^2) + P_L\right]\pi(R_b \cos\alpha)^2 \cos\alpha. \quad (5)$$

This reduces as follows:

$$\frac{\sin\alpha}{\cos^3\alpha} = \frac{\left[\frac{w_1\omega^2}{2g}(R_e^2 - R_i^2) + P_L\right]\pi R_b^2}{\frac{(w_2 - w_1)}{g}\frac{4}{3}\pi R_b^3 R_e\omega^2} = \frac{\frac{w_1\omega^2}{2g}(R_e^2 - R_i^2) + P_L}{\frac{(w_2 - w_1)}{g}\frac{4}{3}R_b R_e\omega^2}. \quad (6)$$

Substituting the fixed conditions given with the statement of the problem in Table I:

$$\frac{\sin\alpha}{\cos^3\alpha} = \frac{0.00003808\omega^2(5.76 - 1.21) + P_L}{0.000194\omega^2} \quad (7)$$

$$\frac{\sin\alpha}{\cos^3\alpha} = \frac{0.000174\omega^2 + P_L}{0.000194\omega^2}. \quad (8)$$

When the clutch is not applied, P_L equals zero and equation (8) becomes:

$$\frac{\sin\alpha}{\cos^3\alpha} = \frac{0.000174}{0.000194} = 0.893. \quad (9)$$

w_1 = 0.0294 lb/in.^{3} = density of auto
transmission oil at 250° F

w_2 = 0.281 lb/in.^{3} = density of steel bal

ω *radians/sec* = rotational velocity of c
housing—(4,500 rpm maximum)

g = 386 in./sec^2 = gravitational acceler

P_L lb/in.^{2} = line pressure applied to clut
(90 psi)

R_i = 1.1 in. = radius of feed-line inl
clutch

R_e = 2.4 in. = radius of centerlin
exhaust ball seat

R_b = 0.093 in. = radius of exhaust ball

α = ½ of the included angle of the co
ball seat

Table I—Values used in the determination o
limits of the exhaust valve cone angle.

Solving by trial and error method:

$$\frac{\sin 32.5^\circ}{\cos^3 32.5^\circ} = 0.8956. \qquad (10)$$

Therefore, for the clutch to release, angle α must be *greater than 32.5°*.

When $P_L = 90$ psi and the clutch housing speed is 4,500 rpm:

$$\omega = \frac{4500 \times 2\pi}{60} = 471. \qquad (11)$$

Equation (8) becomes:

$$\frac{\sin\alpha}{\cos^3\alpha} = \frac{120.8 + 282.5}{135.2} \qquad (12)$$

$$\frac{\sin\alpha}{\cos^3\alpha} = \frac{403.3}{135.2} = 2.98. \qquad (13)$$

Solving by trial and error method:

$$\frac{\sin 50.5^\circ}{\cos^3 50.5^\circ} = 3.01. \qquad (14)$$

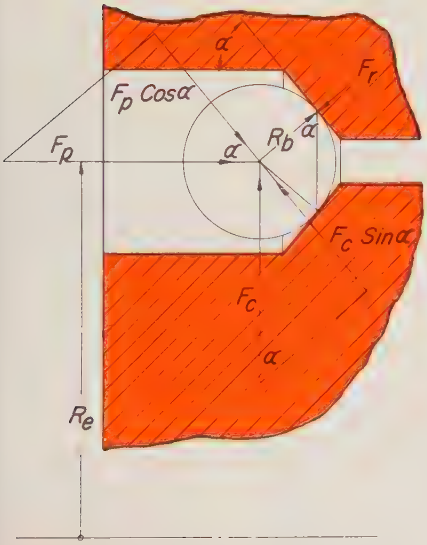


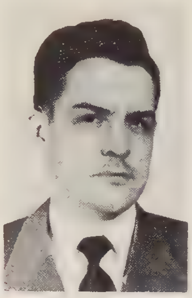
Fig. 2—Cross-sectional drawing showing three forces acting at the balance point of the ball. F_p represents the pressure force tending to seat the ball; F_c represents the effective centrifugal force of the ball; F_r represents the reaction force of the conical seat. If $F_c \sin\alpha = F_p \cos\alpha$, the ball will balance. If $F_c \sin\alpha$ is greater than $F_p \cos\alpha$, the ball will leave its seat.

Consequently, when the line pressure is applied to the clutch, P_L is 90 psi and α must be less than 50.5° for the ball to remain seated to 4,500 rpm. Then, angle α must be *greater than 32.5°* and *less than 50.5°*.

Note that changing the size of the ball would change the seat angle; for example, a ¼-in. diameter ball at the same location would give maximum and minimum limits of 27.5° and 46.5°.

Contributors to GENERAL MOTORS Engineering JOURNAL

March-April 1954

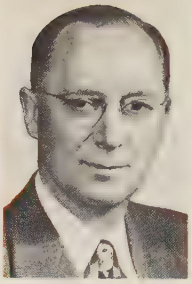


GEORGE A. CAMPBELL, co-contributor of "How Mathematical Reasoning Leads Way to Design of Round Gimbals to Predictable Stiffness," is a senior project engineer in the Experimental Engineering Department, AC Spark Plug Division, Milwaukee, Wisconsin. His most recent project has been concerned with the design of gimbals and components for airborne equipment. The study on which the current paper is based was made in connection with this project.

Mr. Campbell joined AC Spark Plug Division in October 1951 as a project engineer and was promoted to his present position one year later. Previously he had served with the Boeing Airplane Company, Seattle, Washington, from February 1949 to September 1951. There, as an engineer in the Aircraft Controls Group, he was concerned principally with the production engineering phases of the B-47 controls.

He earned the B.S.M.E. degree in February 1949 from the University of Wisconsin where currently he is enrolled working toward the M.S. degree in mechanical engineering. His undergraduate training was interrupted by military service from February 1943 to September 1946. During this period, he attained the rank of first lieutenant in the Corps of Engineers, U. S. Army. His principal assignments were the supervision of several construction projects.

Mr. Campbell is a member of the Society for Experimental Stress Analysis.



RODGER J. EMMERT, contributor of "The Work and Contributions of the Process Development Section," is executive in charge of Facilities and Processes on the General Motors Manufacturing Staff. Facilities and Processes activities include, in addition to the Process Development Section, a number of staff organizations having responsibilities for production engineering, work standards and methods engineering, power, communications, and air transport.

Mr. Emmert was appointed to his present post in 1948 following a period of more than twenty years spent in management responsibilities at several GM Divisions. His General Motors employment began in 1919 when he joined the Remy Electric Division in Detroit as an electrical engineer. Six years later he became tool engineer at the same Division.

He transferred to Dayton in 1927 as factory manager of the Delco Division of Delco-Remy Corporation and two years later was named president and general manager of the Delco Products Corporation, now a General Motors Division. In 1930 he was transferred to the presidency of General Motors Radio Corporation in Dayton. Following two years at this post, he transferred to Pontiac, Michigan, to become factory manager of the Yellow Truck & Coach Manufacturing Corporation (now known as GMC Truck & Coach Division). He continued in this capacity for sixteen years until appointment to his present position.

Mr. Emmert received the B.S.E.E. degree from Case School of Applied Science in 1916. He has been elected to Tau Beta Pi and Sigma Xi honorary fraternities and he is a member of the S.A.E.

E. B. ETCHELLS, contributor of "How Engineers Select Metals for Oil-Film Bearing Applications," is a Chevrolet Motor Division design engineer concerned mainly with the study and evaluation of production designs of rotating and reciprocating engine parts, valve mechanisms, and related parts.

His interest in bearings began in 1934 when he joined the Research Laboratories Division as a junior engineer assigned to the design of engine bearings, connecting rods, and related parts of internal-combustion engines. From 1938 to 1945 he served as assistant head of the Laboratories' Power Plant Department and during this period contributed greatly to the development and application of new types of bearings and bearing materials.

In 1945 he was transferred to his present Division as a project engineer and his first work on the Chevrolet engine involved increasing the durability of the bearings. He later undertook design and development assignments aimed at improving connecting rods, crankshafts, engine mountings, and other engine parts. He became a design engineer in August 1947.

He earned the B.S.E.E. degree in 1932 from University of Michigan and worked two years in the electrical field immediately after graduation.

Mr. Etchells' work has resulted in two patents covering bearing designs. He is a member of the Society of Automotive Engineers and its Vocational Guidance Committee and of the American Society for Testing Materials. He serves on the joint S.A.E.-A.S.T.M. Technical Committee on Automotive Rubber—Automotive Vibration Insulators. His Journal paper is adapted from a paper presented before the American Society of Lubrication Engineers' Symposium in 1952.

RALPH O. HELGEBY,

contributor of "Chemical Engineering Moves Alongside Mechanical Engineering in New Speedometer Design," is an experimental engineer with AC Spark Plug Division. Born and educated in Norway, he has pursued most of his engineering career in this country starting with General Motors in 1925 as a speedometer designer at AC Spark Plug Division. Regular promotions have led to his present position.

Shortly after receiving a degree in mechanical engineering in 1916 from Horten School of Technology in Norway, Mr. Helgeby joined the Norwegian Air Force. He attended the Norwegian Army Air Service Academy after which he was assigned as a test pilot and technical officer. He served until 1923, when he was discharged with the rank of first lieutenant. After leaving the service, Mr. Helgeby was associated with the Norwegian University of Agriculture as a test engineer. When he joined General Motors, he continued his education still further by studying business administration at General Motors Institute. He graduated from G.M.I. in 1926.

Mr. Helgeby's work in the development of mechanical and electrical speedometers and tachometers, flexible shafts, and gear adapters has led to the granting of 35 patents in the field of automotive instrumentation. One of his recent development projects was the Redliner speedometer of which he writes.

Mr. Helgeby's technical affiliations include membership on the Automotive Instrument Standardization Committee of the S.A.E. He also is a member of the Engine Accessories Standardization Working Committee of the Engineer Research and Development Laboratories, Corps of Engineers, U. S. Army.

EDWIN F. KATZ,

co-contributor of "How Mathematical Reasoning Leads Way to Design of Round Gimbals to Predictable Stiffness," serves as experimental engineer in charge of gyro instruments in the Experimental Engineering Department, AC Spark Plug Division, Milwaukee, Wisconsin.

Mr. Katz joined AC Spark Plug in March 1951, soon after earning the M.S. degree in mechanical engineering from Ohio State University. As a senior project engineer, he assumed charge of the gyro group of his Section and later became supervisor of the mechanical engineering projects.

His undergraduate training, also in mechanical engineering, was completed in August 1941 at University of Wisconsin, where he had worked part-time for two years on departmental research and development projects involving fuels, lubricants, and internal-combustion engines. Upon being graduated, Mr. Katz joined Pratt and Whitney, Division of the United Aircraft Corporation and remained until June 1944, working principally on engine design. For two years he was an engineering instructor under the Emergency War Training Program at University of Connecticut, where he had completed part of his master's degree requirements. When this program ended, Mr. Katz became a research engineer in the Physics Department of Battelle Memorial Institute, remaining until March 1950. Before earning his advanced degree and moving to Milwaukee, he served briefly with the Curtiss-Wright Company in Columbus, Ohio.

Mr. Katz has served on committees of the Society of Automotive Engineers and also is a member of the American Society of Mechanical Engineers and of the Society for Experimental Stress Analysis. He is a registered professional engineer, state of Ohio. His previous papers have been on heat transfer and other engineering topics. His master's thesis was entitled "Heat Transfer to Porous Bodies Measured by Cyclic Temperature Variations."

ERNEST A. LEAVENGOOD,

co-contributor of "Designing Simplicity, Ease of Manufacture, and Safety into an Automotive Electrical System," is one of many General Motors engineers who has successfully used an undergraduate training in physics as a stepping stone to project and product engineering. He now is head of the Electrical Section in the Engineering Department, Oldsmobile Division, Lansing, Michigan.

Mr. Leavengood received the B.S. degree in physics from Michigan State College in December 1928, and began work in February 1929 for Oldsmobile at the GM Proving Ground, Milford, Michigan. Assigned to the Experimental Section, his main responsibility was to maintain records on failures and general findings of automotive tests. By 1931, when he was transferred to Lansing, Michigan, he was classified as a special tester.

He continued in the Experimental Department until 1937 when he joined the Electrical Section as a project engineer. His new tasks involved testing and development projects on most of the automotive electrical system, but mainly the radio, its antenna, and the heater.

When the Eastern Aircraft Division of General Motors was established in Trenton, New Jersey, in February 1942, Mr. Leavengood was appointed senior project engineer in charge of the electrical system. More than 3,400 TBM aircraft were produced there during World War II. He returned to Lansing in September 1945 as a senior project engineer in the Section which he now supervises.

VON D. POLHEMUS,

contributor of "An Analysis of the Suspension Problems of the Automotive Vehicle," serves as the engineer in charge of the Structure and Suspension Development Group on the Central Office Engineering Staff, located at the GM Technical Center, north of Detroit.

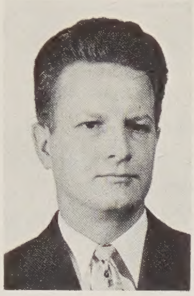
Mr. Polhemus began his career with General Motors in July 1933 with Cadillac Motor Car Division upon being graduated from University of Cincinnati where he earned the B.S.M.E. degree. He worked first as a laboratory assistant on the study of engine friction and, later, on transmission development. In January 1937 he became a senior project engineer with Product Studies No. 2 Group, Central Office Engineering Staff. In 1947 he was made assistant engineer in charge of this Group, and in August 1951 was promoted to his present position as engineer in charge of the Group which now bears the name of Structure and Suspension Development.

Mr. Polhemus' Group undertakes the development of new and better types of chassis and suspensions for passenger vehicles. Many of the designs resulting from these projects have been put into production, in part or total, by the different car-manufacturing Divisions.

His society affiliations include membership in the Society of Automotive Engineers, for which he is a member of the Riding Comfort Subcommittee, and the Engineering Society of Detroit. Mr. Polhemus' work has resulted in one patent on vehicle suspension, granted in December 1952, and many others are now pending in this field.

In March 1950 he presented the paper "Ride Problems Caused by Secondary Vibrations of Rear Suspension" before the S.A.E. and has delivered several technical papers before other technical groups.

ARNOLD B. RANINEN,



co-contributor of "How Mathematical Reasoning Leads Way to Design of Round Gimbals to Predictable Stiffness," is a senior project engineer in the Experimental Engineering Department, AC Spark Plug Division, Milwaukee, Wisconsin. Currently, his work relates to the optical and mechanical design of various airborne components.

Mr. Raninen joined General Motors in June 1940 as a junior engineer in the Engineering Department at Detroit Transmission Division. A short time later he transferred to the Aberdeen Proving Ground, Maryland, where he remained for a period of eleven years, working principally as an ordnance engineer. He returned to General Motors in June 1952 as a special assignments engineer in his present Division.

Mr. Raninen's activities during his later years at Aberdeen were concerned with the design of optical, photographic, missile-tracking, reflecting telescopes. Earlier he contributed to the development of guns, breech blocks, fuses, and test facilities and was engaged in the field and laboratory testing of guns and ammunition.

He earned the B.S.M.E. degree at Michigan College of Mining and Technology in June 1940. While at Aberdeen, he obtained the M.M.E. degree at University of Delaware in June 1951, offering as his thesis "Engineering Design Considerations Pertaining to Reflecting Telescopes Used in Tracking Missiles in Flight." Mr. Raninen is a member of the American Society of Mechanical Engineers.

DONALD W. SEVERANCE,

co-contributor of "Designing Simplicity, Ease of Manufacture, and Safety into an Automotive Electrical System," serves as project engineer in the Electrical Section of the Engineering Department of Oldsmobile Division, Lansing, Michigan. He has been in this Section since February 1946 when he returned from a leave of absence to the Army, having served 26 months in the Southwest Pacific as an electronics officer. He was separated with the rank of captain.

Mr. Severance attended Michigan State College and originally joined General Motors in the Oldsmobile Engineering Department in December 1940 as an engineering clerk in the Design Release Section, which checks and coordinates drawings just prior to their release for manufacture. He went on military leave as a private in June 1941 and completed officer training and several military electronics courses before assuming command of a radar unit overseas. His service education included graduation from Army Electronics School conducted by Harvard University and Massachusetts Institute of Technology. On his return to Oldsmobile, he was promoted to junior project engineer and achieved his present level in September 1949.

Mr. Severance's laboratory work has covered the entire electrical system for Oldsmobile automobiles. He participated in the work of improving the wiring for the 1954 model which is described in his JOURNAL manuscript.

CARL F. SIBBE,

contributor of "Notes About Inventions and Inventors" for this issue, serves as a patent attorney in the Patent Section, Central Office, Detroit.

Mr. Sibbe earned the B.S. degree in mechanical engineering from University of Wisconsin in 1924. He obtained the L.L.B. degree in 1927 from George Washington University, Washington, D. C. While working toward this degree, he was employed as an examiner in the United States Patent Office.

Prior to joining General Motors in 1948, Mr. Sibbe was a patent attorney for the Remington Arms Company, New York City, for three years and served in the same capacity with the American Engineering Company, Philadelphia, for fourteen years. He also was engaged in private practice as a patent attorney for three years.

His association with General Motors began at the Washington office of the Patent Section. In 1951 he transferred to the Central Office, Detroit.

As a patent attorney in the Patent Section, his duties include the handling of patent-infringement questions, the prosecution of patent applications on inventions originating with General Motors employes, and the negotiation of license agreements. Mr. Sibbe is concerned particularly with patent questions connected with vehicle suspensions, heating and ventilating systems, and the negotiation of contracts.

Mr. Sibbe is a member of both the District of Columbia and Michigan bars. In addition, he is a member of the American Bar Association and the American Patent Law Association.

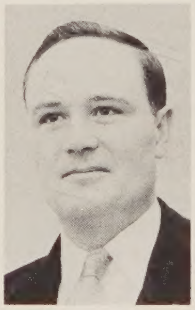
BROOKS H. SHORT,

contributor of "The Physics of Automotive Radio-Interference Elimination," is a staff engineer in charge of the Engineering Research Department, Delco-Remy Division, Anderson, Indiana. As such, he is responsible for developmental work on new products. His Department also is responsible for the suppression of radio noise from Delco-Remy equipment and for the design of special instruments.

Mr. Short received the B.S.E.E. and the M.S. in engineering degrees in 1931 and 1934, respectively, from Purdue University. His advanced study was undertaken while on the electrical engineering faculty during the period from 1931 to 1936. He began the 1936 academic year as an assistant professor of electrical engineering at Clemson College but joined Delco-Remy Division's Engineering Department in December, moving to Anderson full-time in February 1937. He had served Delco-Remy at various times before his graduation, in the Engineering Laboratory as an errand boy and in the Tool Design Department.

Mr. Short advanced from junior engineer to senior engineer in August 1943. He became a staff engineer after World War II.

Almost all of his work has been concerned with novel electrical approaches to automotive problems. His research has resulted in 20 patents and he has contributed to the technical literature with topics on ignition, radio-noise suppression, and moisture-resistant circuitry. He has appeared before student engineering and technical-society audiences at various times. Mr. Short is a member of the Society of Automotive Engineers and has served on subcommittees of the S.A.E. Electrical Equipment Committee. He is a member of Eta Kappa Nu, Tau Beta Pi, and Sigma Xi.



DONALD P. WORDEN,

contributor of "Studies in Resistance Welding Yield Improvements in the Manufacture of Thin-Wall Steel Tubing," is a process engineer in charge of a group of development engineers in the Tubing Process Department at Rochester Products Division, Rochester, New York.

Mr. Worden's background in industrial manufacturing work covers a period of fourteen years at Rochester Products. His early experience was in the maintenance of electrical equipment and services for production. He later was transferred to the Tubing Process Development Department where he worked on varied processing problems. In 1951 he was placed in charge of a group of development engineers in this Department—his present position. Projects completed by this group relate to processing for stainless steel tubing and high-frequency resistance welding, the latter being discussed in his Journal paper. The latter subject also was the basis for a technical lecture which Mr. Worden has given before the American Welding Society.

Two patents covering electrical control devices for aircraft applications, and one patent on an automobile antenna have resulted from Mr. Worden's work. Pending are patents on high-frequency welding equipment and methods.

His technical affiliations include membership in the American Institute of Electrical Engineers.

CLIFFORD C. WRIGLEY,

who prepared the problem in automatic-transmission design, the *Buick Ball*, and the solution appearing in this issue of the Journal, serves as senior project engineer in the Transmission Development Group, General Motors Engineering Staff, GM Technical Center. In his present capacity, he is engaged in future development projects on automatic transmissions.

After earning the B.S. degree in mechanical engineering from University of Colorado in 1935, Mr. Wrigley was granted a fellowship to the Mason Laboratory of Yale University where he did Diesel-engine combustion research and took graduate courses in thermodynamics and mathematics.

Following this he was employed by the Ethyl Corporation Research Laboratories as a mechanical engineer. In December 1942 Mr. Wrigley joined the General Motors Engineering Staff as a test engineer. He was promoted to senior project engineer in March 1944. He has participated in the development of several of the hydraulic transmissions for military and commercial use which are now in production and he has done previous work on the testing and developing of torque converters.

Mr. Wrigley's technical affiliations include membership in the Society of Automotive Engineers, Tau Beta Pi, and Sigma Tau.

Contributors' backgrounds vary greatly in detail but each has achieved a technical responsibility in the field in which he writes.

Faith of the Engineer

I AM AN ENGINEER. In my profession I take deep pride, but without vainglory; to it I owe solemn obligations that I am eager to fulfill.

As an Engineer, I will participate in none but honest enterprise. To him that has engaged my services, as employer or client, I will give the utmost of performance and fidelity.

When needed, my skill and knowledge shall be given without reservation for the public good. From special capacity springs the obligation to use it well in the service of humanity; and I accept the challenge that this implies.

Jealous of the high repute of my calling, I will strive to protect the interests and the good name of any engineer that I know to be deserving; but I will not shrink, should duty dictate, from disclosing the truth regarding anyone that, by unscrupulous act, has shown himself unworthy of the profession.

Since the Age of Stone, human progress has been conditioned by the genius of my professional forebears. By them have been rendered usable to mankind Nature's vast resources of material and energy. By them have been vitalized and turned to practical account the principles of science and the revelations of technology. Except for this heritage of accumulated experience, my efforts would be feeble. I dedicate myself to the dissemination of engineering knowledge, and especially to the instruction of younger members of my profession in all its arts and traditions.

To my fellows I pledge, in the same full measure I ask of them, integrity and fair dealing, tolerance and respect, and devotion to the standards and the dignity of our profession; with the consciousness, always, that our special expertness carries with it the obligation to serve humanity with complete sincerity.

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